ON THE

ANATOMY OF THE

LIVER

Dr BEALE.

ON SOME POINTS

IN THE

ANATOMY OF THE LIVER

OF

MAN AND VERTEBRATE ANIMALS.

By the same Author.

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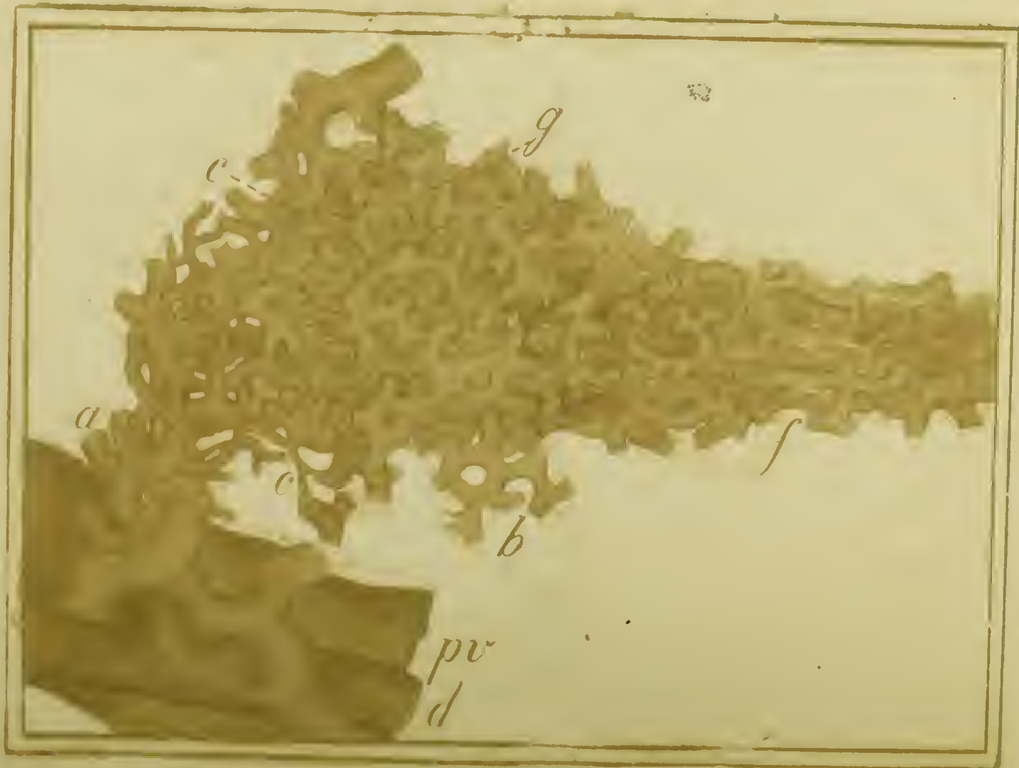

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c
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ON SOME POINTS

IN THE

ANATOMY OF THE LIVER

OF

MAN AND VERTEBRATE ANIMALS,

WITH DIRECTIONS FOR INJECTING THE HEPATIC DUCTS, AND MAKING PREPARATIONS,

BY

LIONEL S. BEALE, M.B., LOND.,

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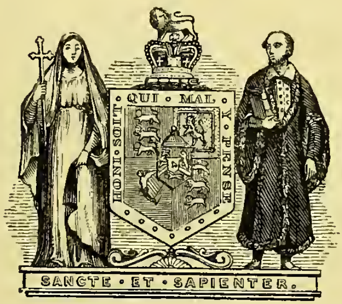

LONDON:

JOHN CHURCHILL, NEW BURLINGTON STREET.

MDCCCLVI.

PREFACE.

The lectures which the author delivered last winter, at King's College, and which were published in the Medical Times and Gazette in the Spring, and his paper in the last volume of the Philosophical Transactions form the basis of the present memoir.

It need hardly be said, that the great expense of illustrating his researches in the usual way would have precluded the author from bringing them forward in a separate form; moreover, the sale of a work like the present must necessarily be very small, as the subject can only be interesting to a limited number of readers. Feeling the necessity of illustrations, he determined, to attempt, although against the advice of some, to take photographs of his drawings. For the success which has attended this effort he is mainly indebted to the assistance and encouragement he has received from several friends who are interested in photography.

The author sees great reason to hope that the plan which has been adopted will be found of great practical utility in illustrating scientific treatises, of which only a few copies are required. In those cases, however, where a considerable number is wanted, the expense of photographs would be much greater than that of engravings, and the length of time required to print them forms a considerable obstacle to their use on a large scale.

For the illustration of scientific subjects the necessary exactness of photographs offers great advantages, and some anatomical structures may be delineated far more like nature in this manner than by engraving. The illustrations in the present volume must not be regarded, by any means, as the most perfect which can be obtained; indeed, several which have since been made have caused the author to become very dissatisfied with those published, many of which were taken from diagrams rather carelessly copied from his drawings. Lately some photographs have been taken directly from the original drawings of specimens of diseased livers in every respect far superior to any in the present volume. Some copies have also been obtained from the objects themselves, which the author hopes to publish at some future time.

In spite of the help and valuable instruction he has received from many kind friends, especially from Mr. Hardwich and from his friend and pupil, Mr. Julius Pollock, the author can only look upon himself as a most indifferent photographer, with a very few months' experience; and he feels that some apology is due from him to those more skilful and experienced than himself, for the wrong he has done their beautiful art, in bringing forward some decidedly bad pictures in a photographic point of view. These delineations may, nevertheless, be sufficiently good to render his views upon the structure of the liver intelligible; for without illustrations, he fears it would be almost impossible for any one to understand his meaning.

Several of the best negatives were kindly taken by Mr. Pollock.

The prints have been worked off in the author's private laboratory.

It may be interesting here to give an account of the

cost of producing these prints. The paper employed was double-crown, at twenty shillings per ream of 26lbs., and was obtained of Messrs. Richards, of St. Martin's Lane.

Cost per 100 copies of each single page :—

	s.	d.
Paper	0	5
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	2	4

One person can finish from 100 to 150 per day, and if the image were brought out by development many more might be obtained in the same time.

The author feels deeply indebted to his friend and colleague, Mr. Bowman, for much valuable advice and for very many suggestions when he was prosecuting his researches, which have rendered the labour not only lighter but far more pleasurable than it could otherwise have been.

Pathological Laboratory,
27, Carey Street,
September 20th, 1856.

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ON THE

ANATOMY OF THE LIVER.

EXPLANATION OF THE FIGURES.

The greater number of the photographs were taken from diagrams copied from the author's drawings. Many of them have been much diminished and some are less distinct than could be wished; but it is hoped that they will in some measure aid in rendering the description, more intelligible. The diagrams from which the photographs were taken, were copied from drawings which had been traced from the preparations with the aid of the neutral tint glass reflector. The magnifying power has been estimated by comparison with the original objects, but it is only to be regarded as approximative. The author feels that many of the delineations are capable of improvement, and since these have been finished he has been enabled to obtain photographs which convey a much more accurate idea of the structure represented, than he at first anticipated, especially in the case of tissues in a morbid state.

Fig. 1. Frontispiece.—Plan of the arrangement of the tissues in a lobule of human liver. The part represented is supposed to be a small segment of a lobule, of which the centre is seen at *e*, and a part of the circumference on the left of the figure. At the lower part are seen branches of the vein, artery, and duct in a small portal canal.

Magnified about 120 diameters.

p. v.—Portal vein.

a. Artery.

d. Duct.

e. Hepatic vein.

The branches of the portal vein, *interlobular*, are seen in the upper and lower part of the figure breaking up into capillaries, which form a solid network throughout the entire lobule. In the meshes of this network are con-

tained the tubes of the cell-containing network. A part of the capillary network is isolated at *b*, and a portion of the cell-containing network at *c*. As the portal capillaries converge towards the central part of the lobule, the meshes of the network become elongated, as shown at *f*, and at length the capillary vessels open directly into the small *intralobular* vein *e*, which carries the blood away from the lobules. Numerous branches of the artery may be traced on the left of the figure pursuing a somewhat tortuous course amongst the other vessels at the circumference of the lobule, and with care a few small branches may be followed which open at length into the portal capillaries near the margin of the lobule, as shown at *g*. It will be observed that the diameter of the smallest arterial branches is considerably less than that of the venous capillaries into which they open. The branches of the duct may be known by their epithelial lining, and may be followed amongst the divisions of the other vessels passing into the lobule. The very narrow ducts are seen to be continuous with the tubular network in which the liver cells lie. The direct continuity of the narrow efferent duct with the wide secreting tubular network which contains the liver cells is shown at *c* and in other situations. At *f* a distinct interval is seen between the walls of the capillaries and the delicate membrane composing the tubes of the cell-containing network, the meshes of which, like those of the capillaries, become much elongated in this part of the lobule. The liver cells situated near the margin of the lobule contain many oil globules, which are not visible in those occupying a more central position.

This drawing is to be regarded as a plan which embodies the results of actual observations made upon many different specimens. It is supposed to be magnified about 120 diameters.

Fig. 2.—Part of surface of an injected human liver, showing the manner in which the vessels are distributed. The duct is not represented.

a. Artery, injected with vermilion, of which only two small branches are represented.

b. Branches of the portal vein, injected with white lead.

c. Branches of the hepatic vein, injected with lake.

The manner in which the *portal vein*, *artery*, and *duct* alternate with branches of the *hepatic vein* is well seen. In the upper part of the figure, at *d*, part of the capillary network of a lobule is represented. The two small white vessels are branches of the artery, which are seen to open into the capillaries near the portal surface of the lobule. The drawing was made with the aid of the neutral tint glass reflector.

Magnified about 16 diameters.

Fig. 3.—Thin section of several lobules of the human liver, showing the general arrangement of the ducts and branches of the portal vein, as they lie in the interlobular fissures.

a. Branches of the *portal vein*, injected with white lead.

b. Small branches of *intralobular vein*, injected with lake. At *c* some of the capillaries of the lobule are represented.

d. Branches of the duct, injected with Prussian blue, ramifying in the interlobular fissures, and giving off but few branches in their course towards the lobules.

The imperfect manner in which the lobules are mapped out in the human

subject, and in most mammalian animals, is shown in this figure. Drawn with the neutral tint glass reflector.

Magnified about 13 diameters.

Fig. 4.—Portal vein, artery, and duct at the margin of a lobule of the human liver. A small branch of the vein is represented at *a*. The branch of the artery may be known by its much straighter course than the branches of the duct, which are seen to be very numerous in this figure.

Magnified 20 diameters.

Fig. 5.—Transverse section of a very small portal canal.

a. Portal vein.

b. Branch of duct, encircling the vein, and giving off branches.

Between the vein and duct, a section of the artery is seen.

Magnified 20 diameters.

Fig. 6.—Very curious anastomosis between small branches of hepatic vein in the human liver, injected with lake. Small vessels are seen opening into the trunks upon all sides.

Magnified about 35 diameters.

Fig. 7.—Interlobular branches of artery partially encircling a lobule of pig's liver. Branches from either side are seen passing off to be distributed to adjacent lobules. Many of the small branches anastomose, and thus an arterial network is formed. At *b* a few of the portal capillaries are represented, and several small branches of the artery are seen to open into them.

Magnified 42 diameters.

Fig. 8.—A small branch of the artery, showing a portion of the network formed by the anastomosis of many of the smallest branches.

Fig. 9.—Two small branches of artery on either side of a branch of duct.—A network is formed upon its coats.

Magnified 10 diameters.

Fig. 10.—Interlobular branches of portal vein of the pig's liver. From either side are represented branches to the contiguous lobules which break up into the capillaries of the lobule ; the latter are only partially injected in this specimen.

Magnified 42 diameters.

Fig. 11.—Distribution of the duct upon the surface of a very small lobule of the pig's liver.

a. Duct with little sacculi in its coats.

b. Small branches of the duct, which are distributed upon the surface of the capsule. These are represented at least twice as wide as they ought to be.

c. Interlobular branch of portal vein.

Magnified 42 diameters.

Fig. 12.—Interlobular branches of vein, artery, and duct of pig's liver.
a. Portal vein, injected with chromate of lead.
b. Hepatic duct, injected with Prussian blue.
c. Artery, injected with vermilion.
d. Small branch of the duct, which passes through thc capsule of the lobule, to be distributed iu the interior.
Magnified 35 diameters.

Fig. 13.—Interlobular branches of the artery and duct of the pig's liver.
e. Artery, injected with vermilion.
f. Duct, injected with Prussian blue.
Magnified 15 diameters.

Fig. 14.—Distribution of interlobular ducts to several adjacent lobules upon the surface of pig's liver, the margins of which are shown by dotted lines. At *g*, and in several other points of the preparation, the injection has passed into the cell-containing network of the lobule, in consequence of which the confused appearance, represented in the drawing, results.

Magnified about 16 diameters.

Fig. 15.—Ducts with vasa aberrantia, injected with Prussian blue, from the transverse fissure of the human liver.

Natural size.

Figs. 16, 17.—Ducts and vasa aberrantia from the transverse fissure of the human liver.

Half the natural size.

Fig. 18.—Dilated portion of a duct, also from the transverse fissure, giving off long straight branches, which pass off to the secreting structure. The irregularity of outline of some of the larger brauches of the duct in this situation is shown at *c*.

Magnified 8 diameters.

Fig. 19.—A part of fig. 16, maguified 4 diameters. The irregular branches of the vasa aberrautia are seen in this figure anastomosing freely with each other, and forming a lax network ; at *e*, the trunk gives off a smaller branch. Branches are observed coming off from all parts of the circumference of the larger ducts in this situation.

Fig. 20.—Interlobular duct with lateral appendages and irregular branched ducts, or vasa aberrantia. The greater uumber of the lateral chaunels do not project beyond the outer surface of the fibrous coat of the duct *a*. In the human liver the orifices of these chaunels form a straight line on opposite sides of the ducts.

b. A smaller branch with uumerous sacculi not projecting beyond the fibrous coat ; as this branch becomes uarrower and less sacculated its coat is seen to become much thinner.

Figs. 21, 22, 23.—Portions of interlobular ducts.

Fig. 24.—Transverse section of portions of three lobules of the horse's liver.

a. Branch of the hepatic or intralobular vein.
b. Interlobular fissure.

The radiating lines of cells are very clearly shown in the specimen from which the drawing was taken. They are connected together here and there by narrow oblique or transverse lines. Near the interlobular fissures the cells cease, but with care, the tubes may still be traced for some distance in the fissure, as faint lines.

Magnified about 35 diameters.

Fig. 25.—Vasa aberrantia from the transverse fissure of the human liver, injected with Prussian blue. The large pale vessels are branches of the portal vein, which are seen to communicate with each other by means of transverse branches. The sacculated ducts are seen running between two branches of the vein. The dark vessel is a branch of the artery which was injected with vermilion, accompanied by two branches of the vein, injected with white lead. In the coats of the gall bladder, in the transverse fissure, and in the larger portal canals, the disposition of the vessels is very similar, each small branch of the artery being accompanied by two branches of the vein. The numerous sacculi are remarkable, and the appearance of this preparation by reflected light is very beautiful. The very dark appearance of some of the cœcal pouches, is caused by their being completely filled with injection.

Magnified 25 diameters.

Fig. 26.—Branches of duct from the pig's liver, showing the parietal sacculi arranged all round the duct, and fully injected with vermilion. The coats of the duct are not represented.

a. Small interlobular duct, the coats of which are very thin and do not contain cavities in their walls.
b. Two very large branched sacculi.

Fig. 27.—Termination of a small interlobular duct in the pig's liver. The smallest branches, which are not more than 1-3000th of an inch in diameter, are seen to dilate into much wider tubes in which the liver cells lie. The portion of the cell-containing network, seen distinctly in the preparation, is only represented in the figure, but its further extension is shown by dotted lines. The shading marks the points to which the Prussian blue injection had reached. In many places it was observed amongst the cells. The liver, from which this preparation was taken, was very fatty. If this had not been the case, that part of the network represented in this figure would not have been found filled with cells, but would consist only of a network of narrow ducts.

a. A portion of the cell-containing network, into which the injection has passed. The cells are seen to be slightly separated from each other, and are nearly surrounded by the injection.
b. A few cells within a portion of the tubular membrane, showing the irregularity of their arrangement. They appear to lie free within the tube and not to be adherent to its walls.

c. Another portion of the tubular membrane, containing granular matter alone, showing outline of tube, the thickness of which has been much exaggerated in the drawing.

These figures have been copied as accurately as possible, and have been photographed from the drawings.

Magnified 100 diameters.

Fig. 28.—A small portal canal from the liver of the seal. The portal vein and artery have been injected with plain size and the duct with Prussian blue.

a. Artery.

b. Small branch of the duct, dividing into its terminal branches which are continuous with the tubes of the cell-containing network, situated upon the thin walls of the transparent and distended portal vein. Some of the tubes, containing small liver cells, are represented at *c*, ramifying upon the coats of the vein, and these have been partially injected. At the lower part of the largest branch of the duct is represented some of the epithelium which lines it, from which the injection has been removed. No fibrous or areolar tissue can be distinguished in this preparation.

Magnified 120 diameters.

Fig. 29.—A transverse section of a small portal canal from the seal's liver, prepared in the same manner as the last figure.

d. A small branch of the portal vein, cut across obliquely.

e. Transverse section of the artery.

f. Smallest branches of the duct and their termination in the cell-containing network.

g. Branch of the duct, uninjected at this part in consequence of the accumulation of its epithelium. Close to the latter, a divided capillary is represented. The largest duct is divided transversely, just at the point where this branch opens into it.

h. A few cells of the epithelial lining of the vein.

Many of the small ducts are compressed, and therefore not clearly distinguishable as such in this figure.

Fig. 30.—Interlobular duct from the rabbit's liver, injected, and at the same time considerably distended, with Prussian blue. The outline of the portal vein, which is injected with colourless size, is represented by dotted lines. The small trunk of the duct is seen to divide into branches upon the surface of the vein. Many of its small terminal divisions anastomose with each other and form a lax network, which is in direct continuity with that of the lobule. At the lower part of the figure, to the left, a portion of the lobular network is represented. The liver cells were much disintegrated from disease, and for the most part the tubes of the cell-containing network were occupied with granular matter, in which a very few small cells were present. The injection, consequently, penetrated very readily for a considerable distance, into the cell-containing network.

Magnified 150 diameters.

Fig. 31.—Thin edge of a rabbit's liver about the natural size, to show the manner in which the *portal canals* and the *hepatic venous canals* alternate with each other, a point well seen in this liver, as the course of the larger vessels is comparatively straight.

The branches of the vein, artery, and duct are somewhat confused in the photograph.

Fig. 32.—Tubes of the cell-containing network enormously distended with injection, showing the extent to which this distension may be carried without rupture.

Magnified 150 diameters.

Fig. 33.—Small ducts from the seal's liver, injected with Prussian blue, showing their continuity with the cell-containing network. A small branch of the portal vein is shown in outline in the upper part of the figure, and in the same situation the continuity of two small ducts with the tubes of the cell-containing network is seen. In the lower part of the figure some of these small ducts may be traced for a short distance into the lobule, before they join, or become continuous with, the tubes of the network. Injected with Prussian blue.

Magnified 150 diameters.

Fig. 33a.—Liver cells from the rabbit, lying within tube of basement membrane, which has been torn away with them. The walls of the tube shrink very much where they are not kept apart by its contents.

Magnified 150 diameters.

Fig. 34.—Portion of a small interlobular duct of the lamb, showing the character of its epithelial lining. Some of the liver cells are also represented.

Magnified 200 diameters.

Fig. 35.—Interlobular duct and artery, from a small portal canal of the cat.

Magnified 200 diameters.

Fig. 36.—A small branch of the hepatic vein from the seal. The constrictions are produced by a projection, into the interior, of the lining membrane, which is surrounded at certain intervals by a narrow circular band of muscular fibres, lying between the lining membrane and the external coat of the vein. At the lower part of the figure is represented a portion of the cell-containing network.

Magnified 200 diameters.

Fig. 37.—Interlobular duct with sacculi from the pig's liver, injected with Prussian blue. The sacculi are arranged entirely round the duct. Their neck is not more than 1-5000th of an inch in diameter. The interrupted lines indicate the fibrous coat of the duct.

d. Small artery.

Magnified 20 diameters.

Fig. 38.—One of the parietal sacculi magnified 110 diameters. The epithelial lining is shown, and has been forced to the lower part of its cavity by the accumulation of the injection.

b. Wall of sacculus, extending a little beyond the outer coat of the duct.

Fig. 39.—Interlobular ducts with branches to cell-containing network of the lobule, and a few parietal sacculi, from the human fœtus about the ninth month.

a. Cell-containing network of lobule.
c. Anastomoses of some of the small branches of the duct as they lie in the fibrous coat of the larger one. Injected with Prussian blue.
Magnified 20 diameters.

Fig. 40.—A preparation, similar to the last, from the fœtal calf, showing branches of duct passing to the secreting structure and parietal sacculi. Injected with Prussian blue.

a. Part of cell-containing network.
c. Anastomoses between some of the finest branches of the duct.
Magnified 20 diameters.

Fig. 40a.—Interlobular ducts with fine branches to lobule from the human fœtus.

a. Anastomoses between finest branches.
b. Cell-containing network of lobule.
c. Sacculi and branches in the fibrous coats of the duct, opening into its cavity by a row of orifices on each side of the tube.
d. Small branch of portal vein, surrounded by a few branches of the duct.
Magnified 25 diameters.

Fig. 41.—Thin section of a part of the margin of a lobule, with a portion of the interlobular fissure, from the liver of a man forty-three years of age. The liver cells have been rendered indistinct by the action of a weak solution of soda, in which this preparation had been hardened.

a. The point where the *ductal* part of the tube becomes dilated into the secreting portion which contains the liver cells.
b. Section of portal capillary.
c. Section of small artery.
Magnified 150 diameters.

Fig. 42.—A similar specimen from the same liver which has been much flattened in consequence of having been subjected to great pressure between the glasses.

e. Epithelium within the finest branches of the duct.
Magnified 150 diameters.

Fig. 43.—Another preparation from the same liver, showing meshes of cell-containing network.

g. Portion of finest duct flattened from pressure.
Magnified 150 diameters.

Fig. 44.—Capillaries of lobule, *d*, with tube of cell-containing network between them, from the human liver.
Magnified 300 diameters.

Fig. 45.—Portion of cell-containing network of lobules of human liver, very much stretched. *f h.* Capillaries very faintly represented.
Magnified 300 diameters.

Fig. 46.—A small duct at the point where it becomes continuous with the cell-containing network, from the human liver. The cells are much altered from the mode of preparing the specimen, and the duct is much distended with injection.
Magnified about 110 diameters.

Fig. 47.—Small portion of the capsule of a lobule of the pig's liver, showing the delicate fibrous tissue of which it consists.

Fig. 48.—An interlobular duct from the pig's liver dividing into smaller branches upon the surface of a lobule. Injected with Prussian blue. The injection has entered the superficial portion of the cell-containing network, producing the mottled appearance represented.
Magnified 20 diameters.

Fig. 49.—Portion of the network of a lobule of the pig's liver much shrunken, and not containing liver cells, an appearance produced in preparing the specimen.
Magnified 110 diameters.

Fig. 50.—Branches of tubes of cell-containing network of the pig's liver.
Magnified 110 diameters.

Fig. 51.—A part of the most superficial portion of the tubular network of the lobule of the pig's liver. These tubes lie partly in the fibrous capsule itself, and partly within the capsule. The tubes contain a few small cells, free oil globules, and granular matter. Partially injected.
Magnified 110 diameters.

Fig. 52.—Portion of cell-containing network from within the lobule of the pig's liver. Partially injected with Prussian blue.
Magnified 110 diameters.

Fig. 53.—A small portion of the network represented in fig. 51, distended with injection.

Fig. 54.—Small branches of the portal vein with capillary network partly injected with vermilion. From the eel's liver.
Magnified 110 diameters.

Fig. 55.—Portion of the cell-containing network from the liver of another eel which had been kept without food for some time. The oil globules are

evidently contained in the interior of tubes, but the membrane of which their walls are composed, is of such extreme tenuity that its outline can only be distinctly traced as a sharp line, in some situations.

a. Transverse branch, connecting two tubes.

Magnified 110 diameters.

These two figures were photographed directly from the drawings, which were originally traced upon paper with the aid of the neutral tint glass reflector. The tubes represented in fig. 55 fit into the meshes between the capillaries represented in fig. 54. These two drawings taken together seem to establish in the most decided manner the presence of a tube of delicate basement membrane, quite distinct from the walls of the vessels, in which the liver cells are contained. The author has still in his possession the preparations from which these drawings were taken.

Fig. 56.—Portion of cell-containing network from a fœtal calf, to show that the tubes may contain two or three rows of cells at an early stage of development.

Magnified 180 diameters.

Fig. 57.—Tubes of cell-containing network from a fœtal snake containing several rows of cells.

Magnified 150 diameters.

Fig. 58.—Part of the cell-containing network of the dog's liver, in which the branches are parallel with each other, altered by being soaked for some time in a dilute alcoholic solution of caustic soda. A few cells are still seen apparently entire, but the greater number are fused together as it were, and the tubes are principally occupied with a highly refracting substance in which numerous oil globules are seen.

c. A tube stretched and separated from its neighbours showing its basement membrane and contents.

Magnified 180 diameters.

Fig. 59.—Small portions of tubes of cell-containing network of the horse.

Magnified 180 diameters.

Fig. 60.—Portion of cell-containing network from the liver of a girl.

Fig. 61.—Portion of cell-containing network of human fœtus at the point of entrance of a small branch of the portal vein as it is about to divide into capillaries. The meshes of the cell-containing network at this point are much wider than at a greater distance from the circumference of the lobule, in consequence of the vessels being larger. The outline of the capillaries and of the tubes of the network are distinctly seen in this preparation, and are separated by a perfectly transparent material.

Magnified about 150 diameters.

Fig. 62.—Portion of cell-containing network of the hedgehog.

Magnified 180 diameters.

Fig. 63.—Portion of cell-containing network of the Guinea-pig.

Fig. 64.—Small branches of duct and their connexion with cell-containing network. From the sturgeon. Injected with Prussian blue.

Magnified 35 diameters.

b. Portion of cell-containing network much distended with oil globules. From the sturgeon.

c. Small branch of duct at its junction with one of the large tubes.

x. Remnants of capillary vessels.

Magnified 200 diameters.

Fig. 65.—Branches of duct and cell-containing network from the frog-fish (Lophius piscatorias).

d. Ducts injected with Prussian blue. Natural size.

e f i. Portions of cell-containing network.

g h k. Minute ducts and branches to network. The shading shows the extent to which the injection has passed.

l. Portion of trunk of small duct showing epithelium in its interior.

m. Portion of duct with epithelium in its interior. The walls are composed of an outer layer of longitudinal fibres, and an inner layer consisting of circular fibres, probably muscular.

e g h i k l m. Magnified 150 diameters.

Fig. 66.—Ducts and cell-containing network, from the liver of the flounder.

a. Small duct with branches.

b c d e. Smaller branches continuous with cell-containing network, with a few crystals in the interior of the one marked *b.*

f. Part of tube of network.

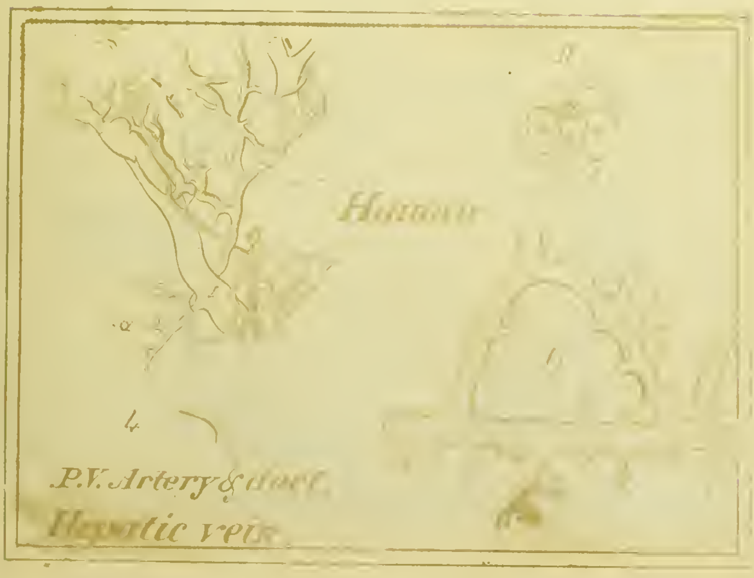
g. Capillaries of lobule much contracted and irregular from the mode of preparing the specimen.

h. Tubes of cell-containing network with biliary matter precipitated in the form of a highly refractive substance, in the interior. In many situations the mass has broken, and the fragments have become separated from each other by a short interval, the tube of basement membrane having remained entire, as represented at *i.*

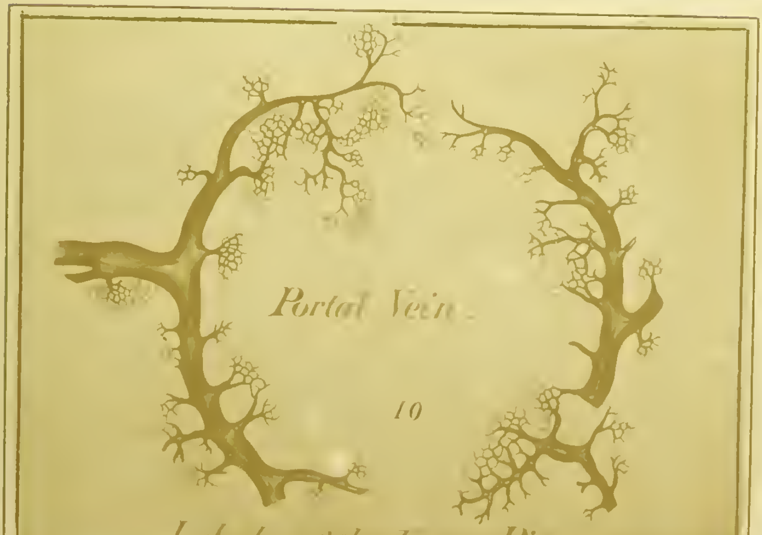
Magnified 150 diameters.


c
c
d
a
b
2


3


Human
4
P.V. Artery & duct
Hepatic vein

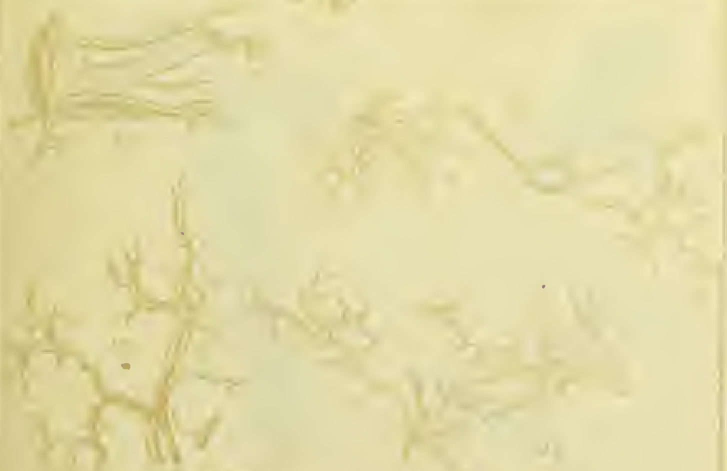
Lobule of liver. Pig.



Lobule of the liver. Pig.

[illegible] of [illegible] of the liver.

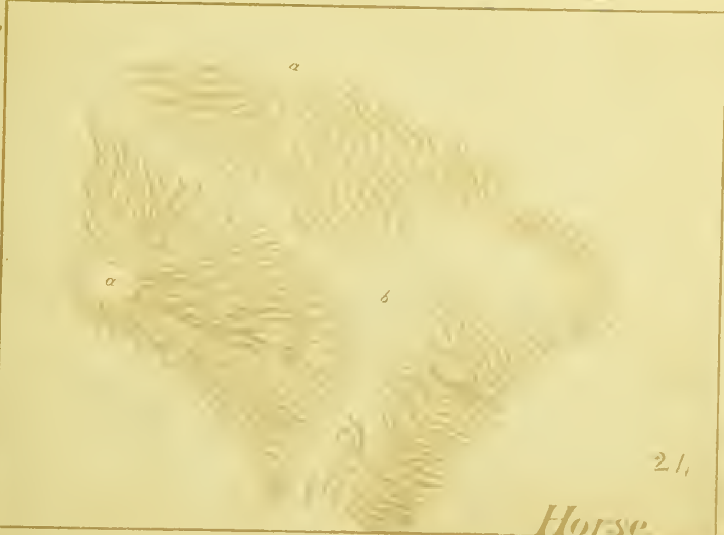
Fig.



[illegible]

Human.

Human



24.
Horse.


25
Human.

Fig. 7

Seal.

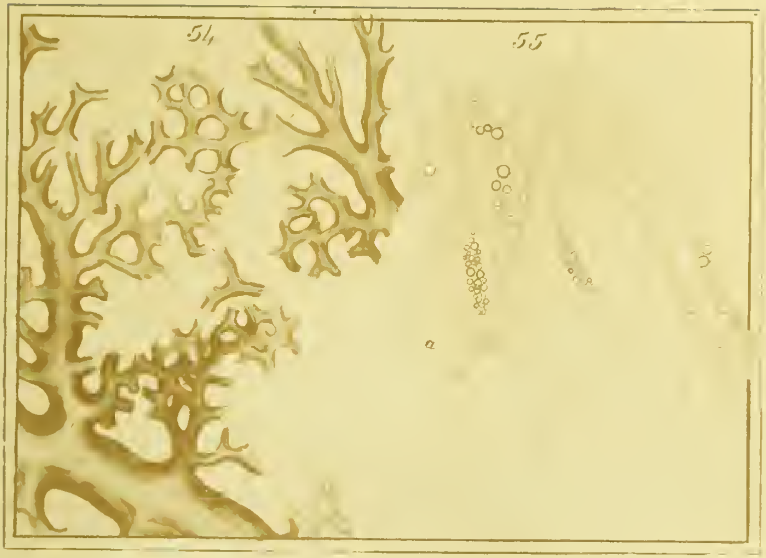
Rabbit


Lamb.
Cat.


Pig.
d
37
38
a
a
39
40
Human Fœtus.
Fœtal Calf.


b
d
40
Human Fœtus.


Human.


54
55
a


a
Dog.
56
Fœtal Calf.
57
b
c
58
59
60
Girl.
Horse.
61
d
62
Hedgehog.
63
Guinea pig.


Sturgeon.

MINUTE ANATOMY OF THE LIVER.

CHAPTER I.

OF THE METHOD OF INVESTIGATION.—HARDENING THE LIVER.—SYRUP.—ALCOHOL AND SODA; THEIR USE IN RENDERING ALBUMINOUS TISSUES TRANSPARENT.—METHOD OF INJECTING THE DUCTS OF THE LIVER AND THE HEPATIC CELL-CONTAINING NETWORK. — OPAQUE INJECTIONS. — TRANSPARENT INJECTIONS.—PRUSSIAN BLUE.—DIRECTIONS FOR INJECTING THE DUCTS OF A LIVER FOR EXAMINATION WITH HIGH POWERS OF THE MICROSCOPE.—PREPARING THE INJECTING FLUID.—OF INJECTING THE VEINS WITH PLAIN SIZE.—PREPARATION OF SPECIMENS PREVIOUS TO EXAMINATION IN THE MICROSCOPE.

In the following inquiry I have employed several methods of investigation which differ in many important particulars, as far as I am able to ascertain, from those which have been followed by other observers. As I believe that my success is to be attributed solely to the methods employed in the inquiry, it seems to me important that they should be described in detail before the results of the investigations are referred to.

METHOD OF PREPARING SPECIMENS TO SHOW THE CONTINUITY OF THE DUCTS WITH THE CELL-CONTAINING NETWORK.

I have not found it possible to demonstrate very satisfactorily the arrangement of the ducts and cell-containing network of the liver, without previous preparation, although I have succeeded in making it out, in some instances, in perfectly fresh specimens examined in glycerine. The difficulty of deciding the point in recent preparations need not excite surprise if the extreme softness of the liver and the difficulty of cutting thin sections

are taken into consideration. Some observers altogether object to observations made upon specimens which have undergone previous preparation, forgetting that water often exerts a more powerful influence in altering the natural appearance of the structure than many of the fluids to the use of which they object. The alteration in the appearance of a structure effected by the refractive power of the medium in which it is immersed is often very great, and must be taken into consideration in examining different textures. Thus, the same body presents a very different appearance when examined in air, water, syrup, oil, or Canada balsam, although neither of these media may have any chemical action on the substance immersed in them. Again, a delicate tubular membrane will entirely collapse in a limpid fluid like water, while in syrup or glycerine it would retain its original appearance. In the first case all tubular character would be lost, while in the second, it would remain distinct. In the present investigation it is important to consider these points.

Hardening the Liver.—In order to show the minute ducts in an uninjected specimen, it is necessary to harden the liver. This hardening may be effected by placing small pieces in syrup for some weeks, or in dilute alcohol to which a few drops of solution of soda have been added. Of the value of this last mixture I cannot speak too highly. No mode of preparation has afforded me such satisfactory specimens, not only of the liver, but of many other tissues, as the one referred to. The advantage of this solution seems to depend upon the opposite action of the two fluids. The alcohol precipitates albuminous compounds, and renders them hard and opaque. The soda, on the other hand, softens and dissolves them, rendering them transparent. In conjunction, these operate in rendering the tissue quite hard and transparent at the same time. I am still prosecuting experiments with this fluid. Large preparations have been preserved in the alkaline fluid with advantage. I have a beautiful preparation of the fœtus, about the fourteenth week, showing the ossification of all the bones. The condition of those of the extremities is particularly interesting. All the textures are perfectly transparent, while the calcareous matter remains opaque.

In this manner the portion of liver is made perfectly hard, but

at the same time transparent. A thin section is to be made with a very sharp, thin knife, then slightly washed and examined in dilute alcohol or glycerine. In many of the sections thus prepared, the appearances represented in some of the drawings in the present volume were produced. The same success is by no means always met with, and it is necessary to examine numerous specimens treated in different ways. Some of my preparations were obtained from the livers of animals in which the duct had been tied some hours before death; and others were taken from organs into the duct of which injection had been gradually forced until it would contain no more. Small pieces were then hardened, and examined after the lapse of some time.

But, although, in many instances, I was able to satisfy myself of the truth of the most important points which I have to bring forward with regard to the arrangement of the minute ducts, a vast number of the preparations failed altogether, and I could not *demonstrate* the arrangement in every liver which I tried, so that I was compelled to resort to new means of preparation. Injection I had tried many times, and had only succeeded so far as consisted in driving the bile into the small ducts. I could not force the injection far enough. The injection usually only reached the surface of the hepatic cell-containing network, and, in many instances, accumulated at this point, in which cases, the appearance of a duct terminating in a blind extremity was produced.

Method of Injecting the Ducts of the Liver, and the Hepatic Cell-containing Network.—Although I felt certain of the correctness of my observations upon uninjected specimens, it appeared to be absolutely necessary to inject both the ducts, and from these, the cell-containing network, before their continuity could be regarded as proved. The presence of the bile in the ducts always prevented the passage of the injection into their most minute ramifications, and no long continued pressure, which I applied by means of a high column of fluid, or with a syringe, was sufficient to force this bile through the thin walls of the duct, and give place to my injection. A most imperfect injection or rupture was the invariable result. After some time it occurred to me to endeavour in the first place to force out the bile by injecting the vascular capillaries with water, and, to my great delight, in the

very first specimen I tried, the gall bladder filled with bile soon after the injection of the portal vein had been commenced, and bile also escaped from the common duct. After a short time, almost pure water ran out from the duct. The water was allowed to escape from the vessels, and then the liver placed in cloths to soak up the water with which it was saturated. The duct, after the lapse of a few hours, was injected. I have examined the water which escaped from the duct upon several occasions. It always contained a large quantity of cylindrical epithelium, and sometimes circular cells from the small ducts were found; but I have never met with specimens of liver-cells, which is easily accounted for, when we consider the small calibre of the smallest ducts. In rare instances these are, no doubt, much larger than natural, in which case the entrance of the hepatic cells would not be prevented. I see, therefore, no reason to doubt the accuracy of Mr. Wharton Jones's observation, although I am unable to confirm it from actual observation.

The injection passed into the ducts very readily and with slight force; and could be seen entering the lobules upon the external surface. It did not appear gradually round the circumference of the lobule, as is the case when the portal vein is injected, but it formed small roundish points, to the unaided eye, almost like little extravasations, here and there at the outside of the lobules; and it then spread for a short distance towards the central part. Upon examining a small piece with the microscope, the small ducts were well seen, and it was evident that they not only went up to the lobules, but that they penetrated into their substance.

Transparent Injections.—Although the injection evidently had not extravasated, the outline of the network was not distinct, and upon examining thin sections with a quarter, only a confused appearance was visible, and I was unable to demonstrate the relation of the cells to the ducts and to the vessels. Before I could hope to make out this point, it was clearly necessary not only to inject the ducts, but to inject them in such a manner that they would bear examination with the higher powers (at least a quarter). After trying unsuccessfully many opaque injections, it occurred to me that a transparent injection might succeed better. Camboge, Carmine, Cochineal, Lake, and some other colouring matters were

employed, but the injection permeated the delicate basement membrane of the tubes and the adjacent textures were equally coloured, so that the nature of the arrangement was still undecided. Freshly-prepared Prussian blue was tried, and with much better success. Now, however, a new difficulty presented itself. The thinnest sections which could be obtained, necessarily consisted of several planes of the cell-containing network and capillaries, and, in consequence of the distension of the former by the injection, the latter could not be distinguished. It then occurred to me to try to inject both the portal vein and the duct; the former with plain size, and the latter with Prussian blue. In a liver prepared in this manner I was fortunate enough to see in several different sections, with a quarter of an inch, the blue *transparent* injection in one tube in close juxtaposition to a colourless capillary vessel injected with plain size. By varying the kind of injection, and resorting to many experiments which it would be useless to recount, I have gradually arrived at a plan of procedure by which specimens can almost always be obtained which will bear examination with a quarter, or even with an eighth of an inch object glass.

Extravasation into the Lymphatics.—Often when too great force is employed, rupture of the walls of a small duct occurs, when the injection not unfrequently passes into a lymphatic vessel, and in this way, as was shown by Kiernan, the abundant plexus of lymphatics in the large portal canals can be injected. In one instance the injection passed into the thoracic duct. A similar result likewise occurred to me in a rabbit. This accidental injection of the lymphatics has been noticed by many. Mascagni long ago noticed that when injection was thrown into the ducts it returned colourless by the absorbents. Although the lymphatics are so easily injected, I have not been successful in my attempts to ascertain how these vessels commence in the liver, and have not yet seen them distinctly in portal canals less than the quarter of an inch in diameter.

DIRECTIONS FOR INJECTING A LIVER FOR EXAMINATION WITH HIGH POWERS OF THE MICROSCOPE.

The portal vein is to be injected with tepid water until the blood is washed out and the whole organ becomes nearly colour-

less. After a time water only slightly tinged with blood will escape from the hepatic vein, while at the same time almost pure water will pass out from the gall duct. The force used must be as gentle as possible, for otherwise some of the minute vessels will be ruptured, and the preparation will not succeed. After the vessels have been fully distended in this manner, the water is allowed to escape from them, and the liver wrapped up in two or three soft cloths, which will absorb much more of the water. The cloths are to be changed when soddened with water. In the course of from twelve to twenty-four hours, the liver will appear shrivelled, and of a soft clayey consistence. It is now ready to be injected from the duct. A mixture of about two-thirds water, and one-third spirit, in which recently precipitated Prussian blue is suspended, is strained through two or three layers of the finest muslin, and carefully injected into the duct, applying slight, but gradually increased, pressure. The injection should be performed with a small half-ounce or ounce syringe, or by pressure of the fluid placed in a glass tube about four feet high.

As soon as the blue injection is seen at several points at the circumference of the lobules, and more fluid cannot easily be forced into the duct, it is better to wait a few hours, and then inject a little more; but the injection of the duct must not be pushed too far, for although in some places no colour whatever is to be seen, in other parts a good injection has, perhaps, been effected. After the duct has been injected, the liver is again set aside for a few hours in damp cloths, so that the superfluous fluid may be absorbed.

Preparation of the Injection.—The Prussian blue is prepared in the usual way, by adding gradually a solution of Ferrocyanide of Potassium to a very dilute solution of Perchloride of Iron. The mixture should be of a dark colour, but should contain no flocculi. It should not deposit a precipitate even after it has been allowed to stand for some time. Without care an abundant deposit of Prussian blue is obtained, which does not flow well. The mixture should have the appearance of a dark-blue solution, rather than of a deposit held in suspension. The addition of a little spirit has the advantage of hardening the delicate walls of the smaller ducts as the injection passes into them, and thus preventing their

rupture. The great advantage of the Prussian blue arises from the circumstance that the precipitate is so fine as to appear like a solution; but still the minute particles cannot be made to pass through the basement membrane of the ducts.

The addition of glycerine to this fluid causes it to flow better. The following is the composition of the injecting fluid which I have been lately in the habit of using. It is well adapted for all ordinary purposes of injection. It is used cold, and it does not run out from the openings of the divided vessels when a thin section is made—a disadvantage from which few injecting fluids which can be used cold are free.

Glycerine	1 oz.
Wood Naphtha	1½ drachm.
Spirits of Wine	1 oz.
Water	4 oz.
Ferrocyanide of Potassium	12 grs.
Tincture of Sesquichloride of Iron*	1 drachm.

The Ferrocyanide of Potassium is to be dissolved in an ounce of the water, and the Tincture of Sesquichloride of Iron added to another ounce. These solutions are to be mixed very gradually, and well shaken in a bottle, *the iron being added to the Ferrocyanide of Potassium.* When thoroughly mixed these solutions should produce a dark-blue mixture, in which no precipitate or flocculi are observable.

The naphtha is to be mixed with the spirit; and the glycerine, and the remaining two ounces of the water added. It is important to mix the solutions in the above order, for otherwise a dense precipitate and free flocculi which will not run well are formed.

Lastly, the colourless fluid is to be mixed gradually with the Prussian blue, the whole being well agitated in a large bottle during the admixture.

Injection of the Portal Vein and Hepatic Artery with plain Size.—After the duct has been injected in the manner above referred to, the liver is placed in warm water, and when it has become warm through the portal vein and hepatic artery are to be injected with fine size. If the injection of the duct has been well conducted,

* The Tinct. Ferri Sesquichlor. of the London Pharmacopœia, commonly known as *Muriated Tincture of Iron*, is recommended because it is a solution of a persalt of Iron, which can always be readily obtained of uniform strength.

and rupture of its coats has not taken place, the fluid which escapes from the hepatic vein will not have the slightest blue tinge; but if this should be the case, we may still proceed, as it often happens that, although extravasation has occurred from the duct into the vessels, the escape has only taken place into one of the smaller branches; and as the vessels do not anastomose, it only affects the lobules supplied by the branch of vein in which the opening has been made.

When size runs out at the hepatic vein, the open end of the latter may be tied, and a little more carefully injected into the portal vessels, in order to distend the capillary plexus. Lastly, a little size is injected into the duct, in order to distend the larger ducts, and to prevent the injection from returning after it has been forced into the smaller branches. When the liver appears filled, it may be placed in cold water until the size sets.

By varying the plan above described somewhat, the different vessels may be injected with different colours. I have succeeded in injecting a human liver with four colours. The portal vein is injected with Flake White, the artery with Vermilion, the hepatic vein with Lake, and the duct with Prussian Blue. From this liver I have obtained specimens which show very clearly many of the points which I shall describe, and many of these preparations have been preserved. In this liver, as would be supposed, it is difficult to find a part in which the vessels and ducts are well injected, but such specimens have been obtained.

PREPARATION OF SPECIMENS PREVIOUS TO EXAMINATION IN THE MICROSCOPE.

When the ducts and portal vein have been successfully injected in the manner described, the greatest care is required in preparing the section for examination. A very sharp knife, or Valentin's knife, in good order, may be employed. The thinnest section, after very careful washing, must be placed in a drop of syrup, or glycerine, and the glass cover so applied as to press very slightly upon the specimen. If the washing be not carefully conducted, the superficial cells will be removed, and the vessels will collapse. On the other hand, if all the cells and *debris* adhering to the surface of the section are not washed off, the preparation will

appear confused and indefinite. The sections should bear examination with a quarter or eighth of an inch object-glass.

It is, of course, very difficult, and, in great measure, a matter of chance, to obtain a section including the course of the smallest duct, and it will often be necessary to examine very many sections before a demonstrative specimen can be obtained. When we consider how difficult it is to obtain a section of the mammalian kidney, showing, even for a short distance, the convolutions of a single uriniferous tube, it need not excite surprise that it is rare to obtain a section of the liver, which shows clearly the termination of the smallest branches of the duct, for these tubes in passing only a very short distance, often occupy many very different planes. The circumstances which render the demonstration of the course of the uriniferous tube very difficult, operate still more forcibly in the case of the liver, as the tubes are very much smaller, the tissue of which they are composed infinitely more delicate, and the entire organ so soft that very slight manipulation is sufficient entirely to destroy the relative positions of the anatomical elements of which it is composed.

CHAPTER II.

GENERAL DESCRIPTION OF THE LIVER.—DIMENSIONS.—BULK. WEIGHT.—SPECIFIC GRAVITY.—CHEMICAL COMPOSITION.—PORTAL CANALS.—HEPATIC VENOUS CANALS.—LOBULES OF THE PIG AND OF OTHER ANIMALS.—CAPSULE OF THE LOBULES.—PORTAL CANALS AND INTERLOBULAR FISSURES.—GLISSON'S CAPSULE.—MANNER IN WHICH THE MAPPING OUT INTO DISTINCT PORTIONS IS PRODUCED.

For much that is known of the anatomy of the liver, we are indebted to the labors of one of the greatest living anatomists, Mr. Kiernan, and almost every one is well acquainted with his most valuable researches upon the structure of this gland.* These investigations were made nearly a quarter of a century ago, at a time when the compound microscope was a very imperfect instrument, and principally with the aid of a lens alone. The liver-cells, the great agents in the secretion of bile, were hardly known, and the exact arrangement of the capillary vessels was not satisfactorily demonstrated until many years after. Yet very much of of that which Mr. Kiernan did, and the correctness of the conclusions which he arrived at, have been fully confirmed by later investigators. The latest researches appear to militate most strongly against the inferences of Mr. Kiernan with reference to the manner in which the ducts commence; but there is, I think, little doubt, that he was, in the main, right, and the conclusions which I have arrived at in investigating many of my own preparations were foreshadowed by him at a time when the means of observation were very imperfect in comparison to those which we may now employ.

Dimensions, Weight, and Chemical Composition of the Healthy Liver.—The liver in health measures about 12 inches from side to side, and 6 or 7 in its antero-posterior diameter. Its bulk corresponds to nearly 100 cubic inches, and its weight varies from 3 to 4 pounds, according to the quantity of blood which it may contain

* On the Anatomy and Physiology of the Liver. Phil. Trans. 1833.

at the time it is examined. Its specific gravity in health is about 1·05.

The following is an analysis of a liver presumed to be healthy. The organ was taken from the body of a man 31 years of age, who was killed by falling from a second-floor window while in the enjoyment of perfect health.

		Per 100 of Solid Matter.
Water...	68·58	
Solid matter ...	31·42	
Fatty matter	3·82	12·16
Albumen ...	4·67	14·86
Extractive matter	5·40	17·18
Alkaline salts	1·17	3·72
Vessels, &c., insoluble in water ...	16·03	51·01
Earthy salts	·33	1·05
	100·00	

In disease, the proportion of these constituents is liable to very great variation. In fatty degeneration an enormous amount of fatty matter may accumulate in the organ. In one remarkable case, I obtained from a liver 75·07 per cent. of solid matter, and of this 65·19 consisted of fatty matter.* In scrofulous degeneration of the liver, the albuminous materials and the water are increased, while the fatty matter is diminished in quantity.

The liver is essentially composed of certain elementary structures, which are common to all secreting organs possessing ducts, although in the different glands these structures are variously modified to serve special ends, which differ in each individual organ. These essential structural elements are the following:—*Cells*, lying in a cavity composed of basement membrane, which have the power of separating certain peculiar substances from the blood, for which alone they have any attraction. *Vessels*, which bring the blood into close proximity with the cells, and *Efferent Ducts*, in direct continuity with the cavity in which the secreting cells are contained, which carry off the secretion after it has been elaborated.

It is impossible to help being forcibly struck with the manner in which these anatomical elements are arranged in this organ, for the same disposition of the parts which economizes material and

* Diseases of the Liver. Dr. Budd. Second edition.

space in the greatest possible degree, provides for the most complete and perfect action of the cells upon the blood. While the latter fluid is made to pass slowly through an extensive series of tortuous channels, it is only separated from the cells by a delicate membrane of extreme tenuity, through the intervention of which it bathes the greater part of the surface of each individual cell.

In the liver the capillary network is of a very unusual extent, a circumstance which alone would lead us to infer that the change exerted upon the blood as it passes through the organ is of a very important nature, and one which must be effected completely. The system of efferent ducts is extensive, and their course before they make their exit from the organ, a very intricate one. The coats of the larger ducts are largely supplied with arterial blood, and the arrangement of vessels around all of them is peculiar.

Portal Canals and Hepatic Venous Canals.—In the compact mammalian liver there are two important series of channels, which in their ultimate distribution may be said to alternate with each other (fig. 2). Of these, one set contains branches of the portal vein, hepatic artery, and hepatic duct, while the other series contains branches of the hepatic vein alone, with the vascular branches which are supplied to their coats. Such an arrangement permits of a very equable and free distribution of the blood to the capillaries of the individual lobules, of which the organ is made up, and promotes its rapid removal after the proper changes have taken place in it; while at the same time the carrying off of the bile after its elaboration is effectually provided for, and the occurrence of other changes in it during its course to the gall bladder and common duct is facilitated. Upon the under-surface of the liver is a large groove, the *longitudinal fissure*, from which passes off transversely upon the surface of the right lobe another depression, the *transverse fissure.* At this point the *portal vein*, the *hepatic artery*, and *nerve-fibres*, enter the substance of the organ; and the *hepatic duct* and numerous *lymphatic vessels* emerge from it. These structures all lie in close proximity to each other, and, in the larger channels, are bound together by a certain quantity of areolar tissue.

From the *transverse fissure* may be traced numerous tubular passages throughout the entire substance of the liver, those most

distant being of course the smallest. They all contain branches of the vessels above enumerated, and in this way no portion of hepatic tissue is at a greater distance from one of these canals than the one-thirtieth of an inch. These tubular passages have been named *portal canals*, by Mr. Kiernan. From the oblique notch on the posterior thick border, can be traced another series of channels, which contain branches of the hepatic vein, and every part of the liver is brought into an equally close relation with one of these canals, which have been termed by the same observer *hepatic venous canals*. Such is this beautiful arrangement, of which there is no other example, by which the vessels are brought into close relation with every portion of this large and compact gland; and thus an even distribution of the blood to each individual part is insured.

From this general survey of the arrangement of the vessels of the liver, we pass naturally to the consideration of the lobules.

LOBULES OF THE LIVER.

If the surface of a liver be examined, it is perceived to be mapped out, as it were, into a number of little spaces, about the size of a small hemp-seed, but differing slightly from each other in dimensions and form. The appearance of these markings is different in the livers of different animals. In the pig each little space is completely circumscribed, but, in the human subject, they seem to fit into, or in a manner appear to dovetail with each other. In other mammalian animals the markings are more or less distinct than in the human subject, but in no one are these spaces defined in the perfect manner in which they are in the pig. If a section be made in various directions in different parts of the organ, a similar mapping out is seen, although, perhaps, it is not quite so distinct as upon the surface. The structure of all these little component masses of the liver is similar. Each little mass, whether it be perfectly circumscribed, as in the pig, or less completely so as is the case in other animals, is termed a "lobule." A lobule, then, contains all the essential elements for the secretion of bile, and for effecting those changes in the blood which this fluid is known to undergo in its passage through the capillary vessels.

Lobules of the Pig's Liver.—A lobule contains all the elements of the liver. The entire organ is a collection of lobules. Every lobule may be regarded as an elementary liver. The small liver of the mouse differs from the large liver of the elephant in a certain degree with respect to the size of the lobules, but enormously with regard to their number.

Now, the lobule is most perfectly seen in the pig's liver, and also in that of the polar bear, according to Müller, and in that of the Octodon Cummingii (one of the Rodents), according to the observations of Hyrtl; and these livers, in their anatomical arrangement, differ vastly from those of other animals with which I am acquainted, as regards the separation of the lobules from each other. With care, a portion of the liver of the pig may be separated into a number of small roundish masses, like very small peas. Each is invested with a firm, fibrous membrane of its own; and, if it be pressed strongly, it bursts, and its contents may be squeezed out. Upon the surface of this lobule ramify small twigs of the *portal vein, hepatic artery,* and *hepatic duct;* many branches from these perforate the capsule at various points, and are distributed *in the interior of the lobule.*

The capsule of the lobule is composed of a variety of fibrous tissue. The fibres are exceedingly delicate, and so arranged as to surround small apertures, through which branches of the vessels and duct pass to the interior. The capsules of adjacent lobules are connected together by the branches of these vessels, and, in many instances, by a small quantity of fibrous tissue.

Many observers describe the lobules of the pig's liver as being surrounded with an expansion of the capsule of Glisson, an arrangement which is sanctioned by Kölliker, who considers that the fibrous material forms partitions between the lobules instead of forming a distinct and separate capsule to each lobule. If a piece of fresh pig's liver be injected with alcohol, to which a few drops of a solution of soda have been added, from the portal vein, and then the whole soaked in the same solution for a few days until it has become hard, the lobules can be readily separated in the manner above described. In very thin sections, from well prepared specimens in which the vessels have been injected, the separate outlines of the capsules of adjacent lobules may be dis-

tinctly seen; there is an interval between them in which the vessels lie. I have one or two preparations in which this point is distinctly seen, figs. 11 and 14.

At one particular spot, and here only, a small twig of the hepatic vein perforates the capsule, and receives on all sides the capillaries from the interior of the lobule, which converge towards this small central or intralobular vein. If the hepatic vein be injected, and the lobules separated from each other to a great extent, but left attached to the small branches of the vein, they would seem to be arranged upon the terminal branches of the vein, almost like leaves upon their leafstalk. In attempting partially or completely to isolate the lobules from each other, the branches of vessels distributed upon their surface are, of course, much torn, since, in all instances, the vessels conducted to the lobules in the portal canals (*portal vein, hepatic artery*, and *hepatic duct*) are *interlobular*, that is, run between the lobules, and give off branches to those among which they pass, as they pursue a somewhat tortuous and irregular course. Such is the anatomical arrangement and connexion with each other of the small circumscribed portions of hepatic tissue of the liver of the pig and polar bear. The entire organ is built up of a number of elementary masses connected with each other, not by continuity of the capillary vessels, or of the secreting structure of the lobule, but only by the vessels for their supply, and by a little areolar tissue in which these vessels ramify. This separation into lobules serves to give a certain compactness to the entire organ as a whole, while at the same time it allows great alteration in volume, and a certain mobility between each of its elementary parts.

This arrangement in the pig's liver would permit a certain amount of separation and movement upon each other of the different lobules, while it would also have the effect of preventing undue engorgement and distension of any—a provision which, from the habits of the pig, seems needed more than in the case of any other animal. A pig's liver will easily contain a quantity of water equal to its own weight, which may be injected from the portal vein; and its lateral and antero-posterior dimensions will be increased as much as two inches each way; while, although, by using great force, almost as much fluid may be forced into the

human liver, it only increases from half to three-quarters of an inch in the same directions.

Lobules in Mammalia generally.—In other animals it is impossible to isolate the elementary parts of the organ from each other without leaving a very rough and jagged surface. When this isolation is attempted the surface of the little masses seem to be rough and uneven; their form is irregular, they have evidently been torn. The true secreting portion of the gland is injured in the attempt. In fact, the secreting structure, and capillary plexus of one imperfectly isolated portion of hepatic substance communicates at certain points with the corresponding elements of the neighbouring lobules. The general arrangement of the vessels, however, is essentially the same in all cases. When the lobules are provided with a separate capsule, as in the pig, the portal vessels ramify upon their surface; but where they are not thus isolated from each other, the vessels penetrate into the substance of the gland at tolerably regular distances, lying in channels or interlobular fissures. Sometimes the fissures are flattened and of considerable width, while, in other instances, they may be compared to tubes separated from each other by a certain interval, in which the capillary vessels, and secreting network, of one lobule communicate with those of its neighbours.

The Lobules of the Pig's Liver compared with the Renules of the Kidney of the Porpoise.—The distinct and elementary lobules in the pig's liver may be looked upon as exceptional, and the liver of this animal appears to bear the same anatomical relation to the liver of most other animals, as the much-divided kidney of the porpoise bears to the compact and solid character which this gland presents in the greater number of the mammalia.

In some animals, although the lobules are not invested by a distinct capsule, the mapping out is much more uniform and distinct than it is in others. In the liver of the rabbit, and in that of many rodent animals, as well as in the horse, and some others, the divisions between each little lobule are more distinctly seen than in the human subject, sheep, or ox. Just as we meet with examples of the kidney intermediate between the much-divided organ of the porpoise on the one hand,—occurring in that of the ox, seal, and even in the human fœtus, and the solid kidney

of man and many mammalia, on the other; so we find that in different animals the liver presents corresponding modifications with reference to its division into lobules. The character of the tissue intervening between the lobules which causes this mapping out will be discussed when the nature of *Glisson's capsule* is considered.

Anatomists have been, perhaps, too anxious in their endeavours to show that the livers of animals generally were arranged in a manner similar to that of the pig. It seems to me that we ought rather to look upon the complete isolation of these small ovoid or many-sided lobules in this animal, as exceptional, than to regard it as the arrangement which exists in vertebrate animals generally. It has been found that the lobules of the human liver, and of most other animals, are in many respects very different in their form and disposition from those of the pig.

In all vertebrate animals, the arrangement is such, that the blood after it has left the smallest branches of the portal vein, is made to traverse an extensive system of capillary vessels, from which it is again collected by the small radicles of the hepatic vein. The vessels ramifying in the portal canals seem to alternate with branches of the hepatic vein, as is shown in fig. 31, which represents the thin edge of a rabbit's liver, or in fig. 2, which shows the arrangement in the human liver.

In all cases, the blood, enriched by the absorption of nutrient material from the intestines, is brought by the numerous small branches of the portal vein to the circumference of the lobules, and is then made to traverse the network of capillaries, the branches of which converge towards the central, or *intralobular*, branch of the hepatic vein. The small efferent vein unites with other branches to form at length the large hepatic vein by which the blood is poured into the inferior cava. The blood brought by the artery pursues a course in the same direction, but the bile flows from the central part towards the circumference of the lobule. The bile, and the blood from which this bile is secreted, flow in opposite directions. The bile which is formed is carried away by branches of the duct. These unite to form larger branches, which run close to those of the portal vein and hepatic

artery. The distension of the capillaries with blood in a moderate degree would tend to force the bile towards the ducts, but if the bile accumulated to an unusual extent in the smaller ducts, or if it became so viscid that it would not flow readily through them; or if the bile were prevented from escaping readily from the common duct, the free circulation of the blood through the capillaries of the liver would be interfered with.

PORTAL CANALS.

The course which the portal canals take varies considerably, being sometimes highly tortuous and irregular, and in other instances so straight and even, that they appear to radiate from the transverse fissure of the liver towards the circumference of the lobes, in which case they are seen to alternate with the *hepatic venous canals.* This point is shown in fig. 31, which is a representation of the thin lobe of a rabbit's liver, in which the portal vein has been injected white, the artery red, and the duct dark blue, while the branches of the hepatic vein are yellow. The direction of the portal canals is also tolerably straight in the seal, but less so in the pig. In sections of human liver, the smallest channels seem to alternate in the manner described, and, as it were, to interdigitate with the hepatic venous canals (fig. 2). When the smaller trunks have been divided at right angles, a small hepatic vein is seen to be surrounded by several branches of the portal vein, artery, and duct, nearly equi-distant from it, and a short distance from each other, as represented in fig. 3, in which branches of the portal vein are marked *a*, and those of the hepatic vein *b*. In the thickest part of the liver the course of the portal canals is very tortuous, and a canal lies on many different planes at different parts of its course. When the lobules of the pig are divided, the hepatic vein is seen to be the centre of a space bounded by twigs of the portal vein, artery, and duct, which ramify upon the capsules of the lobules, and give off branches to the interior, as shown in figs. 7, 10, 11. The disposition of the branches of the portal vein is so regular, as to give the idea, when examined by low powers or with the naked eye, of a complete venous ring, in the centre of which is situated a branch of hepatic vein; but this is shown to be a fallacious appearance, by the careful exami-

nation of well-prepared moist specimens with glasses which magnify about 40 diameters. By their mode of ramification the smaller portal vessels more or less imperfectly enclose little spaces, which vary somewhat in form in different animals, and according to the manner in which the section is made.

In the majority of animals the secreting structure and capillaries forming the substance of one lobule, communicate with those of the adjacent ones in the intervals between the channels by which the branches of the vessels reach the lobules. In the pig the complete isolation is dependent partly upon the disposition of the small vessels, but principally upon the presence of the fibrous capsule described in page 14. Branches of vessels which ramify in the portal canals are conducted into the spaces between the lobules, *the interlobular fissures,* and thus reach the margin of the lobules. The triangular interval left by the approximation of three lobules was termed by Mr. Kiernan the *interlobular space.*

GLISSON'S CAPSULE.

This structure since the time of its discoverer, has been described as a most important and essential constituent of the liver. Continuous with the proper capsule of the organ externally, it is said not only to form a sheath for the large vessels as they lie in the portal canals, but to be prolonged with them into the ultimate parts of the gland, and even to form, for each lobule a proper investment, or, as others have described it, a partition between contiguous lobules.

It is an important point to ascertain if the arrangement of this areolar tissue in the liver differs in any very essential particulars from that of other glandular organs.

Mr. Kiernan showed that, in the smaller portal canals, Glisson's capsule did not completely invest the vessels, but was only to be found upon that side of the vein on which the duct and artery were situated.

Most anatomists have failed to demonstrate a trace of areolar tissue within the lobules of the liver. Occasionally, a few fibres of a structure like fibrous tissue may, undoubtedly, be observed in uninjected specimens; but such an appearance is produced by physical alterations of the structures in the lobule, in the prepara-

tion of the specimen, or it is the result of disease. In the lobules of the livers of all the animals which have fallen under my notice, it was impossible to demonstrate any fibrous structure whatever.

Even in the *interlobular fissures* of the human liver, and of others allied to it in structure, I have been unable to detect any fibrous structure. Bowman, Henle, and Vogel have altogether failed to detect any areolar tissue in this situation in the human liver.

Between the capsules of adjacent lobules in the pig's liver, the elements of areolar tissue undoubtedly exist in small quantity. The capsule can be easily demonstrated; its contents can be washed out. It is composed of delicate fibrous tissue quite distinct from the areolar tissue found in the interlobular spaces and portal canals. In the latter situation the ordinary elements of areolar tissue, white and yellow fibrous tissue, and not unfrequently adipose tissue, are met with. It has, however, been pointed out in what important particulars the arrangement of the lobules of the pig's liver differs from that of other animals.

In the human liver, although there is a considerable quantity of areolar tissue surrounding and adhering to the large vessels, at the point where they enter the liver, and in the larger portal canals, this gradually becomes less, and is, at last, quite lost as we approach the smaller portal canals.

The quantity of this fibrous tissue in the large portal canals (Glisson's capsule) varies very much in different animals. In the rodent animals which I have examined, it seems reduced to a minimum (rabbit, rat, mouse). In the seal it is very sparing in quantity.

Structures which may be mistaken for fibrous tissue.—There can be no doubt of the presence of much areolar tissue in the large portal canals of the human subject; but there are, nevertheless, other structures imbedded in this, such as lymphatics and vasa aberrantia, all of which would be included under the head of Glisson's capsule, by a casual observer. In the horse, the external coats of the large duct and portal vein are incorporated at the point where they touch, and here the areolar tissue clearly belongs to the external coat of these vessels. In the rabbit very little areolar tissue is found to accompany or invest the vessels of the liver. This may be readily demonstrated by injecting a

rabbit's liver with plain size. The whole organ becomes transparent, and the course of the small distended veins can be most readily traced. In this animal the capillaries of the liver are large, and injection runs into them very readily. One cannot fail to be struck by the almost total absence of anything which can be described as Glisson's capsule, or fibrous tissue, in this beautiful liver. A little condensed areolar tissue is seen only around the largest veins, and external to this ramifies an abundant plexus of lymphatics. All the vessels are clear and well-defined. The artery can be readily separated from the portal vein, and neither it nor the duct are bound up with the vein in a fibrous sheath. The larger ducts can be readily distinguished from the other vessels, and their small branches, if not injected, can be traced for a long distance by the characteristic epithelium in their interior. In the smaller portal canals the veins and ducts are entirely destitute of any external coat, but their course may, nevertheless, be traced very distinctly.

When the ducts of a liver (human, rabbit, seal, and other animals,) have been injected with Prussian blue, and the portal vein distended with plain size, a transverse section of a portal canal exhibits no structures but the distended veins and ducts, with branches of the artery. The external coat of the large vein is well seen, and consists of a thin layer of condensed areolar tissue; but the duct and artery are not invested with it. In the small portal canals the vein is quite destitute of this external coat, and it lies in immediate contact with the basement membrane of the peripheral portion of the cell-containing network, or with that of the finest ducts, which often form a plexus around it. In fig. 29, which represents a transverse section of a portal canal of the seal's liver, the smaller ducts, of which a few branches only are very imperfectly injected, *f*, are seen passing round the artery, *e*, and portal vein, a small branch of which is shown at *d*. These small ducts in many preparations seem to enclose the artery and duct, as it were, in a sheath, connected with the coat of the portal vein, but the real nature of this apparent connecting sheath is clearly shown in the preparation from which the drawing was taken.

The difficulty of deciding positively upon this point, however,

in every speeimen submitted to examination, is, perhaps, greater than would be supposed from what I have just observed; by manipulation the small vessels in uninjeeted speeimens beeome so altered that it would be impossible to distinguish them from fibrous tissue. On the other hand, it might be urged, that in injeeted speeimens the fibrous tissue is so eompressed by distended vessels as to be almost invisible. Even if this were the ease, in numerous plaees where these vessels were slightly separated from eaeh other, one eould hardly fail to reeognize fibrous tissue if it existed.

The areolar eoat of the vessels and duets is not prolonged upon the small branehes which are given off from the trunks in the larger portal eanals; and, after many careful examinations of the arrangement and eonnexions of the vessels in the portal eanals of many animals, I have been unable to observe anything in the distribution of the areolar tissue around the vessels of the liver differing from its arrangement in many other situations. The vessels of the kidney and of other glands, as is well known, are invested at their entranee, like those of the liver, with mueh areolar tissue, whieh is gradually lost as the vessels approaeh the seereting portion of the gland.

Manner in which the mapping-out into distinct portions is produced.—The eause of the mapping-out of the lobules of the liver in all animals has been eonsidered to be due to the extensive distribution of Glisson's eapsule between them; but in these situations, as has been already remarked, many observers like myself have altogether failed in their attempts to demonstrate sueh a strueture, with the single exeeption of the pig. The fibrous appearanee in the interlobulur spaees of the uninjeeted livers of animals generally, I have shown to be due to the eollapsed state of small branehes of the vein, artery, and espeeially of the duct, whieh are very numerous.

The divisions, or apparent septa, between the ultimate portions of hepatie substanee in the human liver (independent of alterations in vaseular distension so well described by Kiernan) seem to be produeed in part by the arrangement of the smallest branehes of the duet, and partly by that of the vein and artery. In the seal and hedgehog the markings are not very distinet, and the

ducts passing to the lobules are few in number, and have a short and simple course. In the frog and newt, and in the class of fishes generally, the markings are very indistinct, and there is no regular arrangement of small ducts round portions of hepatic tissue similar to that which exists in mammalia. In the uninjected state, and without previous preparation, these small ducts are so stretched and torn by manipulation that it is quite impossible to distinguish the striated appearance which is produced from ordinary fibrous tissue. The lines between the different lobules of the human and other livers, seen by the unaided eye, are, in the majority of cases, due to a difference between the cells at the surface of the lobule close to the ducts, and those in the interior. In the former situation the cells often contain many oil globules, which are white by reflected light, and appear like a distinct line of separation, while in the latter they frequently contain colouring matter alone.

The small ducts which have been referred to in the last paragraph have been represented in figs. 3, 4, and 5. Although numerous branches have been successfully injected in the preparations from which these drawings have been taken, I feel convinced that, from an examination of such specimens alone, a very imperfect idea can be formed of the vast number of these finest ducts existing in the interlobular fissures of a healthy liver.

In the human fœtus, the separations into lobules are very distinctly marked, but the appearance is not due to the presence of a fibrous capsule, or to the existence of a large quantity of fibrous tissue; for in a well prepared specimen every portion of space between one of the lobules, or spaces mapped out, and its neighbour's, can be seen to be occupied with branches of the vein, artery, and duct, which may be injected. In such a preparation the complete absence of any structure like fibrous tissue, is very remarkable.

The mapping-out is really produced by the different appearance of the little elementary portions of liver which are made up of the secreting elements of the gland, which are more or less coloured, and the intervals between these, in which there are no liver-cells, and which are colourless or nearly so. In these intervals the portal vessels and duct reach the circumference of the lobule

and become continuous with the capillaries and cell-containing network of which the secreting structure is composed.

The interlobular spaces are enormously increased in extent in certain cases of disease where the liver-cells at the margin of the lobule have degenerated. This increase, of course, takes place at the expense of the secreting structure of the lobules, which in a section are seen to be much diminished in size. I have a specimen of diseased liver in which the interlobular spaces are as wide as the lobules. That this increased extent, is due to an alteration in the secreting structure of the lobule is certain, because the network which originally contained cells can be distinctly traced, and in many situations contains biliary particles. Such a specimen would have been formerly described as produced by a thickening of Glisson's capsule. The interlobular spaces then are occupied only by branches of the vessels and duct which lie in close proximity to each other, and no structure corresponding to the description of Glisson's capsule is to be detected in this situation.

With reference to the physiological arrangement of the elementary tissues of which the gland is composed, it may, I think, be said that the livers of all vertebrate animals are arranged so as to form more or less isolated portions, or *lobules*; but in a strictly anatomical sense, the term must be confined to the liver of the pig, since it is only in this animal that the individual lobules can be separated from one another.

CHAPTER III.

OF THE VESSELS OF THE LIVER.—PORTAL VEIN.—MANNER IN WHICH THE APPEARANCE OF A VENOUS RING IS PRODUCED. —ARRANGEMENT OF VENOUS BRANCHES IN THE COATS OF THE GALL-BLADDER, TRANSVERSE FISSURE AND LARGER PORTAL CANALS.—HEPATIC ARTERY.—BRANCHES, TO THE CAPSULE, IN THE PORTAL CANALS, OPENING INTO THE PORTAL CAPILLARIES.—DIAMETER OF THE SMALLEST BRANCHES.—HEPATIC DUCT.—COATS OF THE LARGER DUCTS.—EPITHELIUM.—PARIETAL SACCULI.—OFFICE OF VASA ABERRANTIA AND SACCULI.—GALL-BLADDER.—NERVES AND LYMPHATICS.—HEPATIC VEIN.—HEPATIC VEIN IN SEAL.

PORTAL VEIN.

The large portal vein is formed by the union of the veins of the stomach and intestines, the pancreatic and splenic veins, and the veins of the mesentery, omentum, and gall-bladder. The larger trunks of the portal vein pursue their course in the portal canals, as has been described in page 18. The smaller branches may be said, in general terms, to be arranged round the lobules. These often give off twigs to the neighbouring lobules in a stellate manner. The branches upon different sides do not anastomose so as to encircle each lobule with a venous ring, as many authors, following Kiernan's figures, have described and represented, but communicate with each other only through the intervention of capillaries, as Bowman, Kölliker, and some other observers have stated. Gerlach, on the other hand, gives drawings of these anastomosing trunks, the diameter of which he represents as the same round the entire circumference of the lobule. I have not been able to demonstrate such an appearance by any mode of preparation. Even in the pig there is no vascular ring, although to the unaided eye it might appear so. Interlobular branches of the portal vein in the pig's liver are represented in fig. 10. The drawing gives a good idea of their general arrangement. The capillaries are only partially injected. In the liver of the human subject, and in livers allied to it, small branches of the portal vein can

often be traced from the interlobular fissures into the lobule, breaking up into capillaries as they go.

Manner in which the appearance of a Venous Ring is produced.—In dried preparations, owing to the close approximation of trunks which in the recent state had occupied very different planes, an appearance as if the smaller trunks communicated with each other, and thus encircled the lobule in a venous ring, is undoubtedly produced. That such an appearance is fallacious is proved by carefully examining well injected specimens in fluid. For this purpose it is better to use a transparent injection, which can be examined by transmitted light. Very rarely, however, small branches of the vein do anastomose, but this communication is quite exceptional, and a similar anastomosis even occurs, sometimes between branches of the hepatic vein, as represented in fig. 6. The diagramatic representations of most authors would lead to the conclusion that such an arrangement, in the case of the portal vein, was constant, which is not the case.

The mode of distribution of the small branches of the portal vein, in the human subject, is represented in figs. 3 and 4; in the pig, figs. 10 and 12, and in the eel, fig. 54.

Arrangement of Venous Branches in the coats of the Gall-bladder, Transverse Fissure, and larger Portal Canals.—In the coats of the gall-bladder, in the transverse fissure, and in the large portal canals of the human liver, there exists an intimate network of veins, which pour their blood into the large branches of the portal vein. The arrangement of these branches is peculiar and exceedingly beautiful, especially in the gall-bladder, in the coats of which there exists an abundant venous and arterial network. Each branch of artery is accompanied by two branches of vein; and when these sets of vessels are injected with different colours, a very beautiful appearance is produced. I have a preparation in which the artery has been injected with vermilion, and the vein with white lead.

HEPATIC ARTERY.

Branches to the Capsule.—Many branches of the artery pass to the capsule of the liver, in which they ramify abundantly, forming a network having large meshes. These capsular branches and

their anastomoses, are readily injected in the liver of the fœtus or child. They are beautifully seen upon the surface of the pig's liver, and encircle each individual lobule with a ring.

Branches in the Portal Canals.—Each branch of portal vein, in the portal canals, is accompanied with at least one branch of the hepatic artery, figs. 4, 5, 12, 28, 29, and frequently by two or three which communicate with each other by anastomising branches.

The artery gives off numerous branches in the portal canals. The greater number of these are distributed upon the coats of the ducts. The thick walls of the larger ducts are abundantly supplied with arterial blood, fig. 9; but the smaller branches of the duct, the coats of which are extremely delicate, pass through the meshes of an arterial network, fig. 8. In the pig this network may be very readily demonstrated upon the surface of each lobule, as represented in figs. 7 and 8, where it is only imperfectly injected; but in the human subject, and in mammalia generally, the branches are less numerous, and are seen only in the interlobular spaces; other branches supply the coats of the portal and hepatic veins. The greater quantity of blood, after passing through these small arteries, is collected by venous radicles, which empty themselves into branches of the portal vein.

Branches which open into the Portal Capillaries of the Lobule.—A certain proportion, however, of the blood is undoubtedly poured into the capillaries of the lobule, as may be readily proved by injection with different colours. Some very small straight arterial branches may be traced from the portal aspect of the lobule, or from the interlobular fissures, for a short distance into the interior, where they join the capillaries, near the portal surface of the lobule.

The whole of the arterial blood, therefore, which supplies nutriment to the several structures of the liver, passes through the capillaries of the lobule before it is returned to the heart, and no doubt furnishes a small portion of the material from which the bile is formed. The termination of some of the lobular branches of the artery is represented in the frontispiece at *g*, in fig. 2 at *d*, and in fig. 7 at *b*. The hepatic artery was originally regarded by Kiernan as one of the sources of the blood conveyed to the

secreting structure of the liver, by the branches of the portal vein.*

Diameter of the smallest Arterial Branches.—The *meshes* of the network whieh the smallest branehes of the artery contribute to form, are many times wider than those of the venous capillaries in the lobule, fig. 7; but the diameter of the small vessels of whieh this network is eomposed is very much less than that of the portal capillaries. I have measured the diameter of the smallest arterial branches in the pig and in the human subjeet. The average measurements were as follow; but these numbers must be considered rather as approximations to the truth, than as absolutely correet, beeause it is impossible to aseertain to what degree the vessels have been distended by the injeetion:—

	Pig.	Human.
Smallest branches of artery ...	1-4000th of an in.	1-4000th of an in.
Venous capillaries of lobule ...	1-1600th "	1-1300th "
Small ducts on surface of lobule	1-1600th "	1-1800th "
Finest portions of duct	1-2500th "	1-1800th "

Injection of the Venous Capillaries of the Lobule from the Artery.—That the eapillaries of the lobule ean be injected from the artery necessarily follows from the nature of the arrangement just deseribed. In this way, Lieberkühn injeeted the lobules as well as from the portal or hepatie veins. As a general rule, the injection appears first quite at the portal surface of the lobule, and gradually extends towards the eentre; but sometimes the eentral eapillaries are injected from the artery very readily, while the marginal eapillaries are quite free from injeetion. This has oecurred to me both in the human subject and also in the pig; but it was eonfined to eertain small portions of the liver, while in the greater part of the organ, small arteries eould be readily traeed into the marginal eapillaries. In the situations referred to, the branches of the portal vein were very imperfectly injeeted, and the capillaries did not eontain any injeetion, in consequenee, probably, of being filled with fluid previous to injeetion, while the eentral eapillaries were empty. The explanation of this eireumstanee I imagine to be this—that the injeetion having found its way by one ehannel into these eentral eapillary vessels, gradually

* Op. Cit. p. 748.

spread through them, until the appearance above referred to was produced, its course towards the central capillaries being, in the majority of instances, prevented by their distension with blood or serum. If the preparation exhibiting this arrangement, be compared with others from the same liver, its mode of production can be clearly made out. I believe it to be the explanation of the result obtained by some anatomists, who have been led to conclude, from the appearance above indicated, that the small arteries emptied themselves into the capillaries nearer to the intralobular vein, or into this vessel itself.

The whole of the blood, therefore, which has become venous after passing through the arterial network, mixes with that of the portal vein, either before the trunk enters the liver, or into the large branches in the portal canals, or into the lobular capillaries ; and probably takes part in the formation of bile.

Arrangement in Gall-Bladder, &c.—The arrangement of the artery and veins is different in the gall-bladder, and in the transverse fissure of the liver (fig. 25) and large portal canals. In these situations even very small branches of the artery are accompanied by two small branches of the vein. This arrangement appears to facilitate the free return of blood from these parts, and, it seems to me, may be looked upon as a provision for permitting that amount of stretching or pressure to which these vessels must necessarily be subjected, without interfering with the free circulation of blood through them. As the united capacity of the veins is twice that of the artery, the free and equable circulation in these small vessels is insured under all circumstances. The chance of congestion occurring in the portal canals is still further provided against by the communication of the arterial network with the capillaries of the lobule.

HEPATIC DUCT.

The branches of the duct lie in the portal canals with branches of the vein and artery. At least one branch of the duct accompanies each branch of the portal vein, but frequently there are two or three (fig. 12). From the branch or branches accompanying the vein, several smaller ones pass off to the secreting structure. These do not anastomose so as to encircle the lobules.

In the pig, the interlobular ducts, while running between contiguous lobules, are applied, as it were, to the exterior of their capsules, and give off much smaller twigs on either side (figs. 11, 14), which perforate the capsules, and become connected with the secreting structure in the manner described in Chapter V.

Coats of the Larger Ducts.—The coats of the larger ducts are very thick, and composed of fibrous tissue. In their walls, however, are found numerous little cavities opening upon all sides of the interior of the tube, in most animals, but in the human liver (in which, according to my own observations, their form is very irregular; fig. 20), they open, except in the largest trunks, by a line of orifices on opposite sides of the duct, as Kiernan described. These cavities have been generally looked upon as mucous follicles, but I shall speak of them as *Parietal Sacculi,* because their form is not always such that the term *follicle* could be applied to them correctly; neither has it been satisfactorily shown that they are the organs concerned in the secretion of the mucus of the bile. At the point where the smaller ducts open into a larger one, the lining membrane is so disposed as to form a valve which would tend to prevent the passage of the bile from the large duct back again into the smaller branches, while it would not in any way interfere with the course of the fluid in the opposite direction. The course of the small ducts through the walls of large ones is often very oblique, so that they are frequently imbedded in the fibrous coat of the latter for some distance.

Parietal Sacculi.—In the coats of ducts about the 1-125th of an inch in diameter, and in larger ones, many little saccular dilatations are situated. These are the so-called *glands of the ducts.* In the pig, and in many animals which I have examined, they are arranged all round the tube (figs. 26, 37). They may be described, for the most part, as simple oval pouches, connected with the cavity of the duct by a very narrow neck, in the pig, often not the 1-1000th of an inch in diameter (fig. 38). In the larger ducts they are branched, and often run for some distance in the coats. Occasionally the branches of one sacculus anastomose with those of another. The largest are singularly complicated, and project some distance from the duct, lying in the areolar tissue which surrounds it. These sacculi are represented in fig. 26, appended

to ducts which had been injected with vermilion. Some very large branched sacculi are represented at *b*; and at *a*, a small duct, the walls of which are very thin, without sacculi in its coats.

In the human subject a somewhat different arrangement occurs. Instead of being situated entirely round the tube, the openings form two rows or lines, situated upon opposite sides of the ducts. The greater number of these openings are, however, the orifices, not of sacculi, like those in the pig, but of small irregular tubes, which run obliquely for some distance in the coats of the duct, and anastomose with each other (figs. 20, 21, 22, 23). Some of these branches leave the ducts, and anastomose just outside the trunk from which they are given off.

Many of the small ducts, about the 1-80th of an inch in diameter, have numerous cœcal pouches connected with them, arranged pretty close together, gradually becoming shorter as the duct becomes smaller (figs. 20, 23, *b*). The branches springing from these ducts are composed of basement membrane only.

Vasa Aberrantia.—Irregular ducts with cœcal pouches are very numerous in the transverse fissure of the liver, where they form an intimate network connected with the larger branches of the duct in this situation. These were described by Theile as branching mucous glands, but were first noticed and named *vasa aberrantia* by Weber. Not only are the right and left hepatic ducts in the transverse fissure of the liver connected by vasa aberrantia, as Weber was the first to point out, but the anastomosing ducts in this situation are so numerous, that they form a network, which, in well-injected specimens, presents a very beautiful appearance (figs. 15, to 19, and fig. 25). Through the intervention of such branches, all the trunks in the transverse fissure communicate with each other. In the larger portal canals, I have demonstrated the existence of numerous ducts of a similar character. In figs. 19 and 25, some of these beautiful ducts, with their numerous follicular appendages, from the transverse fissure, and at *b* (figs. 20 and 23) from portal canals, are represented.

Some observers, and, lately, Lereboullet,* have altogether failed to demonstrate these curious networks. In every mo-

* Mém. sur la structure intime du foie et sur la nature de l'altération connue sous le nom du foie gras. Paris, 1853.

derately good injection of the ducts, they are seen in great number, although it is not always easy to isolate them, in consequence of the quantity of areolar tissue with which they are surrounded. In order to inject them, it is necessary to force out the bile from the ducts in the first instance, in the manner described in Chapter I. It is, however, difficult to understand how the smaller ducts of a liver could be successfully injected without these tubes being rendered sufficiently distinct.

These ducts are imbedded in areolar tissue, which is abundant in the parts where they are found. In the transverse fissure of the adult, the ducts lie nearer to the hepatic substance than to the coats of the portal vein; but they can be easily removed, without cutting into it. I have been able to trace straight branches from the vasa aberrantia directly into the hepatic substance. The further course of these branches is that of an ordinary duct.

In the fœtus, these curious ducts are much less numerous; their course is less tortuous, and they occur in small patches, in which the branches are seen to be very numerous, and the anastomoses very frequent. The epithelium is more abundant, and the cells large, and dark in colour; so that the injection does not run so readily as in the adult. The quantity of areolar tissue about them is much less than in the adult. The vasa aberrantia lie so close to the hepatic tissue, that it is almost impossible to remove them without a thin layer of the latter, into which they are prolonged at numerous points. There are, nevertheless, many blind extremities connected with them.

Office of the Vasa Aberrantia and Sacculi.—The circumstances which have been alluded to, appear to me to militate strongly against the notion of the vasa aberrantia being modified, and anastomosing mucous glands. They seem rather to point to the ductal nature of these curious channels; and I think it not improbable that they are really altered secreting tubes, and at one time formed a part of the secreting structure of the liver. As the portal vein becomes larger at the termination of intra-uterine life, it is not unreasonable to suppose that the hepatic tissue, close to it, would recede; and that the most superficial portion would become so modified, as to be no longer adapted for

secretion. The cells would become altered, the ducts shortened and contorted, until a condition such as that above described might at last be produced.

In the very thin edge of a horse's liver, which was composed principally of fibrous tissue, I have been enabled to trace the gradual alteration of the ducts through many intermediate stages to the ultimate complete disappearance of secreting cells, until at length nothing remains but a branched tube without any cells in the interior. The ducts, discovered by Mr. Kiernan in the triangular ligament, in the pons hepatis, and in other situations, are probably produced by a similar change.

To the sacculi the office of secreting the mucus which is found in the bile has been assigned by most observers who have investigated this part of the subject, but, from a careful examination of their arrangement, I cannot help doubting the correctness of this inference. Cavities opening into a tube, by a narrow neck, often not more than the 1-5000th of an inch in diameter, seem hardly adapted for the secretion and pouring out of a highly viscid mucus (figs. 37, 38). If these so-called "glands" were the seat of the formation of mucus, one would not expect that injection would so readily enter them, and, from their arrangement, it is clear that it would be difficult to force the mucus out of them; again, the complicated and highly tortuous ducts, which Weber termed very properly "vasa aberrantia," possess no characters which entitle them to be regarded as anastomosing mucous glands, a view which has been advocated by Theile. They are most readily injected, and their walls are much thinner than those of ordinary ducts.

It must be remarked that an abundant venous plexus surrounds the vasa aberrantia (fig. 25) and the larger ducts, and that the bile in the larger ducts, by means of the sacculi, is brought much nearer to the vessels than would be the case in simple tubes with thick fibrous walls. If these little sacculi were mucous glands, one would be led to expect that the bile of animals, in which they were numerous, would be more viscid than that of animals in which they were few in number. I have ascertained that the bile of the rabbit, in which animal these sacculi are almost absent, contains as much mucus as that of the pig, in which they are exceedingly numerous, and arranged entirely round the

ducts. It seems to me that we may regard these appendages connected with the ducts as *diverticula,* in which the bile may be retained temporarily, while it becomes inspissated, and probably undergoes other changes. In fact, I think that we may look upon them as little gall-bladders appended to the ducts.

In the rabbit and guinea-pig these sacculi are very slightly developed. I have not seen them in the ducts of the fishes and reptiles which I have examined.

Coats of the Larger Ducts.—The coats of the larger ducts are composed of condensed fibrous tissue; but there is reason for supposing that they contain a few muscular fibre-cells, although there is no evidence of a distinct muscular coat, at least in the human subject. In some fishes I have seen an internal layer composed of circular fibres, and an external coat of longitudinal fibres (figs. 65 *m,* 66 *a*). In the human subject I have observed, but not very distinctly, indications of a somewhat similar arrangement.

Epithelium.—The epithelium of the larger ducts is of the columnar variety. The cells are large and well-formed, usually exhibiting a distinct nucleus. They are frequently tinged with yellow colouring matter, and often contain yellow granules. In the small ducts, this epithelium becomes shorter, and it approaches more nearly to the tesselated variety. This change in the character of the epithelium is a gradual one. In ducts less than the 1-500th of an inch in diameter the epithelium consists of small round flattened granular cells.

The small branches resulting from the division of the trunks in the interlobular fissures, or upon the surfaces of the lobules in the case of the pig's liver, are composed of basement membrane, and only lined with a single layer of epithelium. These small ducts may, without difficulty, be traced up to the secreting structure of the lobule, but the manner in which they commence, and the relation which they bear to the liver-cells, have long been matters of dispute among anatomists. It has been held by some of the latest authorities, that the ducts commence by blind extremities at the margin of the lobules; by others, that they are open and impinge against the secreting cells; while, according to the researches of some observers, they commence as very narrow inter-

cellular passages between the liver-cells. This part of the subject will be more fully discussed in Chapter V.

GALL-BLADDER.

The gall-bladder may be looked upon as a diverticulum of the hepatic duct. It lies in a fossa underneath the liver. It is of a pear shape, and its fundus is directed downwards and forwards; it terminates in the cystic duct, which is about an inch in length. The *hepatic* duct, formed by the union of the right and left ducts, leaving the liver by the transverse fissure, passes downwards, and soon joins the cystic duct at an acute angle, to form the *ductus communis choledochus,* which is about three inches in length, and lies between the layers of the gastro-hepatic omentum. After coming into close proximity with the pancreatic duct, the common duct enters the coats of the intestine with the latter, and passes obliquely between them for three-quarters of an inch. The ducts open by an orifice common to both at the junction of the descending and transverse portions of the duodenum.

The mucous membrane of the gall-bladder is thrown into reticulated folds, which form the boundaries of numerous polygonal depressions, so that upon its internal surface it presents a honeycombed appearance. It is highly vascular, and is covered with columnar epithelium. The folds are prolonged into the cystic duct, where they are arranged in a crescentic manner, their general direction being that of a spiral, and they have been compared to a spiral valve. The peculiar arrangement of the vessels of the gall-bladder has already been described in page 26.* The cystic artery is derived from the right division of the hepatic, and the veins empty themselves into the vena portæ. The lymphatics are very numerous. The greater part of the thickness of the walls of the gall-bladder is composed of fibrous tissue, but there also exists a layer, in which muscular fibre-cells, taking partly a longitudinal and partly a transverse direction, are found. The human gall-bladder is capable, under ordinary circumstances, of containing about one ounce of fluid; but it undergoes great alterations in

* Through the kindness of his friend, Professor Weber, the author has just had an opportunity of reading his researches upon the anatomy of the liver, in which he refers to the distribution of the vessels upon the gall-bladder, described in p. 26. Weber is the only author who notices this very beautiful and unusual arrangement of the vessels.

volume, and in it the bile becomes inspissated, and undergoes other changes. Dr. Kemp has shown, in some recent experiments, that the mucus of the gall-bladder takes a very active part in altering the character of hepatic bile and converting into cystic bile; changes which consist not merely in its inspissation but in an alteration in its chemical composition.*

The gall-bladder is absent in many fishes; in pigeons, toucans, and some other birds; in the elephant, stag, horse, and tapir; but it is present in the ox, sheep, and antelope. It is always found among reptiles. The reason of its absence in the animals above alluded to has not yet been satisfactorily explained.

Nerves and Lymphatics.—The nerves of the liver are branches of the sympathetic, which are principally distributed upon the artery, and the mode of their arrangement is very similar to that of other arterial trunks. I have not been able to demonstrate them on small branches less than the 1-500th of an inch in diameter.

The lymphatics are abundant in the portal canals and in the transverse fissure, but I have never been able to trace them to their origin. The manner in which the lymphatics may be injected has been described in page 5. If any vessels of the liver be injected with water or size the lymphatics are always distended. I have not been able to demonstrate their presence in portal canals less than the quarter of an inch in diameter.

HEPATIC VEIN.

The radicle of the hepatic vein (intralobular vein) is always seen at a point midway between branches of the portal vein, or in the centre of the lobule in the case of the pig. The capillary meshes are elongated as they approach the hepatic vein, and they converge towards this vessel, the smallest trunk of which is larger than the smallest branch of the portal vein.

If the trunk of an hepatic vein of moderate size be laid open, numerous small openings will be observed upon its interior. These openings correspond to the centres of the lobules which surround the trunk of the vein, as described by Kiernan. It is by reason of the entrance of these minute intralobular branches into the large trunk of the vein, that the latter remains patent when cut across. The small radicles of the hepatic vein receive capillaries on all

* Proceedings of the Royal Society, Vol. VIII., No. 21, p. 133. 1856.

sides, quite down to the point where they emerge from the lobule; and these small intralobular veins, in many instances, open, not into a vessel somewhat larger than themselves, but pour their blood at once into a large trunk. In these points the arrangement of the portal trunks contrasts remarkably with that of the branches of the hepatic vein.

The reason of this difference is clear. In no other manner, consistent with the compact nature of the mammalian liver, and without loss of space, could a part of the portal blood be equally distributed to, and made to pass through, the extensive capillary system existing in the lobules. After having passed through this plexus, the blood is poured into the veins, and carried away from the liver in the most direct manner possible.

Hepatic Vein in the Seal.—In the seal, the capacity of the branches of the hepatic vein within the liver is enormously greater than in other animals, an arrangement which has reference to the accumulation of blood in this organ, and in the great venous sinus into which the trunk of the hepatic vein is dilated, when the animal remains for some time under water. Accumulation of the blood, in the small branches, to an improper extent, is prevented, while its further progress towards the hepatic venous sinus, after its accumulation, is promoted by a beautiful arrangement to which I must briefly refer.

This peculiarity was first noticed by Mr. Kiernan, who describes the external coat as consisting of circular fibres. In the smaller trunks these fibres are arranged in the form of circular fasciculi, external to which is a certain quantity of lax areolar tissue, which permits of great alteration in the volume of the veins taking place.* When the hepatic veins were injected with plain size, I was surprised to find that a beaded appearance was produced, which is represented in fig. 36, in which this arrangement is very well shown. Upon making a section of a small branch of the vein which had been injected, it was seen to be partially divided into a number of small chambers, by means of septa, which are shown in the figure. At the situation of each partition a circular band of muscular fibre-cells, which is enclosed at intervals in the lax fibrous coat, may be very easily demonstrated. It is no doubt the office of

* Op. Cit. p. 738.

these contractile circular partitions to prevent undue distension, to equalize the accumulation of blood in the branches of the vein, to drive it onwards towards the cava, and to prevent undue pressure upon the secreting structure of the lobule, which is separated from the vein when it is distended, by the slight distance represented in fig. 36 at the lower part of the drawing. The arrangement of these fibres is shown in the same figure, and the circular muscular bands are represented as divided transversely.

Occasionally an anastomosis takes place between the small branches of the hepatic vein. One of the most remarkable is represented in fig. 6, which is copied from a preparation taken from the human liver.

CHAPTER IV.

OF THE INTIMATE STRUCTURE OF THE LOBULES OF THE LIVER. —EVIDENCE OF THE EXISTENCE OF A TUBULAR BASEMENT MEMBRANE WITHIN WHICH THE LIVER-CELLS ARE CONTAINED. — DISTENSION OF THE TUBES BY INJECTION. — RADIATION OF THE TUBES FROM THE CENTRE OF THE LOBULE.—DIAMETER OF THE TUBES OF THE NETWORK.— INTERVAL BETWEEN THE WALLS OF THE CAPILLARIES, AND THE MEMBRANE OF THE TUBULAR NETWORK.—CONTENTS OF THE TUBULAR NETWORK OF BASEMENT MEMBRANE.—CELLS.—CONTENTS OF THE CELL.—TUBULAR NETWORK IN FISHES.—OF THE MANNER IN WHICH THE CELLS ARE ARRANGED WITHIN THE TUBULAR MEMBRANE.

A LOBULE of the liver consists of a solid network of capillary vessels, in the meshes of which the liver-cells are seen. Towards the central part of the lobule, the cells assume a more linear direction, and appear to radiate from the intralobular vein as from a centre. It has long been a question whether the cells simply lie in the meshes of the capillary network, or whether they are enclosed in tubes of basement membrane. The cells are prone to become detached in the form of little columns which are often branched, an appearance which is usually considered to be due to the manner in which they are fitted into the vascular meshes, and not to the presence of any tissue surrounding them, which would keep them together in this manner. In these detached masses it is not easy to demonstrate a basement membrane, and their connexion has been accounted for by a supposed adhesion of the cells to each other.

Among the authorities who have advocated the existence of a basement membrane may be mentioned Krukenberg, Schröder Van der Kolk, Retzius, Weber, Theile, Backer, and Leidy, while Kiernan described a *lobular* biliary plexus, the tubes of which were considered by him to be continuous with the ducts, nearly five-

and-twenty years ago. The majority of modern writers have arrived at a totally opposite conclusion, and deny the existence of such a membrane.

EVIDENCE OF THE EXISTENCE OF A TUBULAR BASEMENT MEMBRANE WITHIN WHICH THE LIVER-CELLS ARE CONTAINED.

It is not uncommon to find cells with shreds of delicate membrane attached to them in specimens which have been slightly hardened in dilute alcohol. In fig. 33a are represented two cells from the rabbit's livcr, enclosed in a membrane which can be traced in the interval between them as a very narrow contracted tube. From time to time, upon carefully examining the edge of a thin section of liver, small portions of the network are seen to project, but it is impossible to demonstrate the existence of a basement membrane when the preparation is examined in water or spirit. In sections which have been mounted in glycerine a distinct tubular membrane can often be seen. I have observed the same point in several preparations, but have been unable to preserve the specimens. The extreme thinness and delicate nature of this membrane will readily account for the difficulty of displaying it, and it must be borne in mind, that, in the majority of specimens examined in the ordinary manner, it is impossible to see even the walls of the capillaries, which are so very much thicker and firmer than the membrane alluded to. The difficulty of demonstrating such a membrane seems to me but a very insufficient argument against its existence; and even if it were quite impossiblc to see it, it would hardly be right to conclude that it was absent upon these grounds alone, for it is obviously possible for such a membrane to exist, and to be at the same time quite invisible, unless rendered more or less opaque by some peculiar mode of preparation.

Fusion of the contents of the Membrane.—This delicate basement membrane is well displayed in certain specimens in which a curious chemical change has taken place in the contents of the tube. In a section of dog's liver, which had been soaking for some time in a weak solution of soda, the outer portion of most of the cells appeared to have been dissolved, and, in consequence, a

fusion of their substance had taken place, causing the formation of a highly refracting mass within the basement membrane, the outline of which was rendered very distinct. The appearance of this preparation is represented in fig. 58, and at *c* is shown one of the tubes separated and drawn out, with its contents contracted within it, so that the outline of the membrane itself can be distinctly seen.

In fig. 66, *h*, a somewhat similar change is shown in the liver of a flounder which had been treated with soda, and afterwards by acetic acid, causing the precipitation of some of the constituents of the bile, which had been previously dissolved by the soda. By pressure, some of these highly refractive masses were broken, and by examination with a very dull light the continuity of the delicate basement membrane could be traced between them. When certain specimens of liver have been soaked for some time in strong syrup or glycerine, the cells in the interior of the tubes shrink from exosmose, and the delicate tubular membrane contracts upon its contents. The tubes, therefore, become much narrower, and, except in the highly refracting nature of their contents, the altered cell-containing network closely resembles the capillary network. Such an alteration, as it occurred in a very thin section of pig's liver, is represented in fig. 49.

Capillaries displayed in one section, and Tubular Network in another section, from the same Liver.—In a properly prepared liver it is often possible to demonstrate the cell-containing network in one section, and the capillary network in another. When the vessels are distended with clear size, the meshes of the cell-containing network are seen; but if a section be well washed and placed in glycerine, the sharp, well-defined outlines of the capillary vessels are brought into view. In such a section, from which the cells have been removed, I have seen, in some places just at the thin edge of the specimen, stretched across the space between two capillary vessels, the exceedingly delicate basement membrane of the tube in which the liver-cells lie, recognizable rather from the small quantity of *débris* and granular matter which adheres to it, than from any positive characters distinguishable in the membrane itself. This appearance can only be seen under the influence of a very dull light. I have one preparation pre-

served, in which the basement is demonstrated very satisfactorily. The cells within can be seen, and the delicate tube projects beyond them for a short distance.

Distension of the Tubes by Injection.—The network is capable of being distended to a considerable extent in every part of the lobule without rupture. Often the injection accumulates to such an extent as completely to obscure the cells; and, in consequence of the pressure thus caused, the vessels are rendered invisible. Even in such specimens, the appearance cannot be mistaken for extravasation or vascular injection. In tubes which are only partially injected, the injection often accumulates a little on each side, gradually shading off, as it were, towards the centre; while towards the adjacent capillary vessel it forms a distinct, well-defined, and dark line.

A portion of the cell-containing network, and its junction with some of the finest ducts, from the human subject, injected with Prussian blue, is delineated in fig. 46. The cells represented in this drawing are much altered, from the mode of preparing the specimen. Their position, however, is shown. In the pig, portions of the cell-containing network in different states are represented in figs. 49, 50, 52; in the seal in figs. 28 and 33; in the rabbit in figs. 30, 32, and 33a; and in the dog in fig. 58.

The cells which escape into the surrounding fluid from an injected specimen have portions of injection adhering to them, or are deeply stained with it.

Radiation of the Tubes from the centre of the Lobule.—If a section be made through the lobule, exactly at right angles to a small branch of the intralobular vein, the cells are seen to form rows, which radiate from the centre towards the circumference of the lobule, as has been noticed by Müller, Valentin, Bowman, Theile, Gerlach, and others. In sections made in other directions, this radiated arrangement is not to be shown. Fig. 24 is an exact copy of a section of horse's liver, and is the most beautiful specimen of this arrangement which I have seen. The rows increase in number as they pass from the centre. They are connected at irregular intervals by oblique or transverse branches, often much narrower than a cell, and contain only nuclei and granular matter. These communicating branches are best seen in

injected specimens. The cells of which the rows are composed for the most part form single lines, although here and there, where the tubes are wider than usual, two cells may be seen lying transversely across the tube. A well prepared specimen of this kind appears to me to prove the existence of the tubular network in the lobules of the liver, almost as distinctly as a good preparation of the kidney demonstrates the presence of long tortuous tubes in the cortical portion of that organ.

In specimens in which these radiating tubes have been injected, not only has the existence of a basement membrane been proved, but one distinct from, and not adhering to, the walls of the capillary vessels. The meshes of the capillary network are slightly elongated towards the centre of the lobule, but it is obvious that such an arrangement could not alone account for the appearance observed; for if the cells lay promiscuously in the meshes of the capillaries, without being circumscribed by any basement membrane, the radiating lines would necessarily be connected transversely by numerous cells, forming a wide stratum, but they are only united by narrow tubes containing a single row of cells. Some of these tubes from the human liver are represented in fig. 45, which was taken from an injected specimen.

Diameter of the Tubes of the Network.—The contents of the cell-containing network are liable to considerable alteration in volume, a change which can be readily effected artificially. In the same specimen, the diameter of the network varies, but only to a very limited extent, according to the size and number of the cells within the basement membrane. It is usually about 1-1000th of an inch in diameter in most mammalian animals, and is considerably wider than the narrowest part of the ducts with which it is immediately continuous.

The width of the spaces between the tubes of the network, or, in other words, the diameter of the vessels, varies much in different parts of the lobule of the human liver, being much wider at the portal surface of the lobule, where the small branches of the veins enter, than at a greater depth, where capillaries are alone found. This point is shown in a thin section from the lobule of the liver of the fœtus, represented in fig. 61. The photograph, however, is not so distinct as could be wished.

Interval between the Walls of the Capillaries and the Membrane of the Tubular Network.—In the fœtus there is a distinct interval between the wall of the tube in which the secreting cells lie, and that of the capillary vessels, so that when a good section is obtained, two distinct lines are seen between the hepatic cells and the cavity of the capillaries, fig. 61, *d*. These two lines are separated by a perfectly transparent, apparently structureless substance, in which no trace of fibres can be detected.

The circumstances above enumerated impress me with the idea that the liver is originally composed of two distinct networks, which intimately interdigitate with, or fit into, each other—one, containing the secreting cells,—the other, the blood. As development advances, the walls of these two sets of tubes gradually become incorporated, except in those situations where the capillary network is less dense, or where the meshes of the cell-containing network are more widely separated from each other, in which cases a distinct limitary membrane to the tubes containing the liver-cells can be demonstrated in the adult. The cell-containing network and the vascular network can be alternately distended. The membrane is very permeable to *water* in both directions, as I have proved by first forcing fluid from the vessels into the duct, and afterwards in the opposite direction. Subsequent injection proved that no rupture had taken place. Nevertheless, the greatest force which can be applied will be found insufficient to cause the bile to pass through this delicate membrane into the capillary vessels.

Under some circumstances, then, it is demonstrable that the basement membrane of the cell-containing network is distinct from the walls of the capillaries; but in the greater part of the lobule, where the two membranes come into close contact, they are incorporated, so that really the majority of the liver-cells, except at the points where they are in contact with each other, are surrounded with blood, from which they are only separated by a thin layer of delicate structureless membrane.

The facts which have been brought forward are the most important which I have been able to adduce in favour of the existence of a tube of basement membrane in which the liver-cells lie. According to this view, bile formed at any part of the net-

work would find its way between the cells and the tube of membrane to the margin of the lobule. Upon the other conclusion, which supposes that the cells lie freely in the meshes of the capillary network, the bile formed in the more central part of the lobule is supposed to be transmitted from cell to cell, until at last it reaches those at the circumference of the lobule, and it is further concluded that, in its transmission, it becomes elaborated, by being acted upon by each successive cell of the series. If, then, bile were formed by being passed on from cell to cell in this manner, the materials from which the crude bile is first formed ought to be separated from the blood in the more central parts of the lobule; for otherwise, the blood, rich with recently absorbed constituents, would seem to pass through a considerable extent of that portion of the capillary network at the circumference of the lobule to no purpose.

If the above description of the anatomy of the parts be correct, the precise point of the most active formation of bile should be the outer part of the lobule, for the blood reaches this part first. It will be shown subsequently that this is probably the case. Argument alone would render the existence of such a membrane probable, but, with care, its presence may be actually demonstrated, and by several different methods of preparation.

CONTENTS OF THE TUBULAR NETWORK OF BASEMENT MEMBRANE.

The most important anatomical elements contained in the tubular network of basement membrane are the *liver-cells*; but, besides these, a certain quantity of free granular matter is always present; and not unfrequently oil globules, and granules of dark yellow colouring matter, are met with. In disease, it is not unusual to find the network occupied by a viscid, granular, highly refractive mass, in which only a few nuclei can be observed. Sometimes the network is so shrunken as not to be more than half the diameter of an ordinary healthy hepatic cell, and its contents appear to consist of a viscid material, in which are suspended granules and oil globules. In fishes generally, the tubular network seems to be greatly distended, and entirely occupied by a

mass of oil globules. With care, however, nuclei may sometimes be distinguished among them.

Cells.—The liver-cell varies much in form and size in different animals, and in the liver of the same animal. Its characters have been well described by numerous authors. The cells in different parts of the lobule vary in their characters, as Dr. Handfield Jones has especially pointed out.* The largest cells are not unfrequently as much as the 1-800th of an inch in diameter, the smallest not more than 1-2000th of an inch, or even less.

Each cell contains a nucleus, demonstrated easily in perfectly normal cells; but not to be readily distinguished when the cells contain much oil, and when they have undergone other changes in the course of disease. The nuclei vary considerably in size. Upon an average, they may be said to be about the 1-3000th of an inch in diameter. Generally they are circular, but sometimes they have an oval form. The nucleus contains granules, some being larger than others; often there is a bright point in the central part, which is regarded as the nucleolus.

Each liver-cell of the adult liver usually contains but one nucleus; but, in some instances, two may be observed. The liver-cells of young animals, on the other hand, commonly contain many nuclei. I have observed as many as six or seven in the cells of the calf, about the middle period of gestation.

Contents of the Cell.—In all the animals which have fallen under my notice, the liver-cells, compared with the cells of other glands, are remarkable for their variety of form and size, for their high refractive power, and for containing besides the nucleus, granular matter, and, very frequently, oil globules and granules of yellow colouring matter. Under some circumstances the yellow colouring matter becomes much altered, and so dark, that the cell appears to be occupied by black granules, which are sometimes very numerous. The material of which the cell consists is not of a fluid nature, but highly viscid; so that, upon pressure, the whole cell becomes flattened, and the highly refractive viscid material is

* For the views of Dr. Handfield Jones upon the function of the liver-cell, the reader is referred to his valuable papers in the Philosophical Transactions, 1846, 1849, and 1853, and to a paper in Vol. XXXV. of the Medico-Chirurgical Transactions, 1852.

still seen to form a thin compressed layer. The cells are rounded, oval, or polyhedral in form, and frequently present many irregular angles, with somewhat rounded edges. Not unfrequently the appearance is such as would give one the idea that the cells had been packed together very closely, and thus subjected to pressure unequally distributed. I have not succeeded in demonstrating to my satisfaction the existence of a distinct cell-wall; but at the same time have not yet investigated the matter sufficiently to enable me to express a confident opinion that it does not exist. If the absence of this structure were placed beyond a doubt, the so-called *cells* must be regarded as fragments broken off from a solid, more or less cylindrical mass, originally continuous, in which nuclei were interspersed at intervals,—a view which accords in some degree with that held by E. H. Weber.

Contents of the Tubular Network in Fishes.—Now, in the class of fishes, and in some reptiles and birds, and, according to Dr. Handfield Jones, even in the rat,* the tubes of the cell-containing network do present the appearance of being filled with an uninterrupted mass, composed of oil globules, granular matter, nuclei, and sometimes coloured granules. In fig. 55, which is a drawing of the tubes of the cell-containing network of the common eel (*Anguilla acutirostris*), this point is well shown. The drawing was made with the neutral tint glass reflector; and I have the preparation now in my possession, so that it can be readily compared with the delineation. Here the tubes are seen filled, but not distended with oil globules. The high refractive power of the latter prevents the possibility of seeing the nuclei *in situ;* but in the fluid surrounding the preparation a few were distinctly observed. The eel from which this specimen was taken had been kept for some time without food.

From this preparation the disposition of the contents of the tubular network in fishes is well shown; and it demonstrates, in an uninjected preparation, the existence of the tubular membrane, so difficult to show in this class of animals. Fig. 54 is a drawing of the capillaries of the eel's liver injected, and their arrangement is observed to be similar to that in most animals. The tubes containing the oil globules, represented in the adjacent drawing, form

* Phil. Trans., 1849.

a lax network with very long meshes, or perhaps the specimen might be more correctly described as being composed of parallel tubes, communicating with each other here and there. Now, how can the evidently cylindrical lines of oil globules, depicted in fig. 55, lie in the meshes of this vascular network, unless they be contained within a tube of basement membrane? Of the accuracy of the facts there can be no doubt, and the preparations from which the drawings were made may yet be compared with each other. The only interpretation I can offer is that which I have just advanced, and it seems impossible to associate the two appearances as they exist in nature in any other manner.

In a large number of animals, then, the contents of the tubular network may be said to be continuous; in some it is interrupted so as to form masses irregular in size, in which nuclei are scattered at intervals; and in others, the particles are more uniform in size, resemble each other very closely in general character, and each contains a separate nucleus. Between the numerous, well-defined, and separate masses, or liver-cells of the mammalian animal on the one hand, and the continuous mass which occupies the tubular network of the fish on the other, it is easy to demonstrate every intervening shade of difference; and more than this, at different periods of development of the embryo, and in various morbid conditions of the human liver, every degree of separation and of continuity may be observed. Again: by the action of various chemical reagents, as described in page 40, the distinct and separate cells of the healthy mammalian liver may be made to fuse, as it were, so as to form continuous masses, like those occupying the tubular network of fishes.

In all cases there is room for fluid to pass between the contents of the tube and its walls towards the duct, as may be proved by the passage of injection; and, although to our observation the tubes may appear to be quite full, or even distended, it is obvious that, independent of any change of size in the cells themselves, a very slight diminution in the quantity of blood in the capillaries of the liver would permit the free passage of fluid along these apparently distended tubes.

The facts I have stated tend to lead to the conclusion, that the

liver-cell is rather to be regarded as a collection of viscid matter round a central nucleus, than a true cell provided with a distinct cell wall. There are many circumstances in favour of such a view, but I shall not now bring these forward, neither shall I attempt to offer a positive opinion on the matter until some observations I am making are completed. I may, however, be permitted to observe that, although such a conclusion would be altogether at variance with the results of the observations of almost all previous observers,—and if true of the liver-cell, must also be true of the cells of renal epithelium, and of those of some other glands,—it would be, in some measure, in accordance with a view upon the nature of cells lately advocated by Professor Huxley.*

Of the manner in which the Cells are arranged within the Tubular Membrane.—In the livers of adult mammalia which I have examined, the cells for the most part lie in a single row, although, as before observed, some portions of the network have been found to contain two or three rows lying across the tube, while in other situations the space within the tubular membrane is so contracted as not to admit one cell of the ordinary size, in which case it is occupied only by granular matter, and a viscid material which refracts highly. The following mammalian livers have been examined with reference to this point,—that of the human subject, pig, dog, cat, rat, rabbit, horse, seal, and some others.

I have never seen such an appearance as has been delineated by Leidy, who has represented three cells lying across the tube; nor have I observed anything agreeing with the description or drawings of Lereboullet, who figures two rows of cells, and represents a mass of injection passing between them. My own observations lead me to conclude that the cells lie somewhat irregularly, as above described, and differ totally in their arrangement from that of the renal tubes, where there is a central cavity. Bile would escape from the cells, and pass probably in an irregular manner, sometimes on one side of the tube, sometimes on the other, between the cell and the wall of the tube;—at least this is the way in which injection can be made to pass in the direction opposite to that in which the bile flows naturally.

* The Cell Theory, by T. H. Huxley, F.R.S., *Medico-Chirurgical Review*, October, 1853.

In the only embryos of mammalia which I have examined, more than one row of cells is contained within the tube, and two or three are commonly met with (human fœtus, fœtus of ox). The cells are smaller than in the adult liver, the tubes not unfrequently being larger. In birds also (linnet, turkey, starling, fowl), two or three cells lie within the tube in some places, but in others only one is met with. In the embryo-chick numerous rows of cells are seen lying across the tube.

In those reptiles which I have observed, there are often several cells lying across the tube (frog, adder, field-snake); in fishes, so far as my observation goes, there is also room for many rows of cells (flounder, frog-fish, sturgeon, herring, cod, &c.).

It may be said, generally, that the tubes are most narrow amongst mammalia, and widest amongst fishes. The cells also are well defined in the former, but not often demonstrable in the latter class. The similarity of the arrangement of the cells in the tubes of the embryos of man and the higher animals, with the embryonic, as well as the permanent, condition which they assume in the lower vertebrata, and in many of the invertebrata, is a point which must excite great interest, and is one which has a parallel in the case of other glands and many tissues. There is perhaps no more striking example of this gradual progress from the lower and simpler form of structure to the higher and more elaborate than the one here adduced.

CHAPTER V.

OF THE ULTIMATE RAMIFICATIONS OF THE DUCTS, AND OF THEIR CONNEXION WITH THE CELL-CONTAINING NETWORK. —ANASTOMOSES OF THE DUCTS.—OF THE FINEST BRANCHES OF THE DUCTS, AND OF THEIR JUNCTION WITH THE SECRETING TUBES OF THE CELL-CONTAINING NETWORK; MAMMALIA; BIRDS; REPTILES; FISHES. —EPITHELIUM OF THE SMALLER DUCTS.—DR. HANDFIELD JONES' VIEWS.

Numerous observers, who have carefully investigated the matter, differ widely in the conclusions they have arrived at with regard to the manner in which the most minute ducts commence in the liver; and are at issue with reference to their mode of connexion with the secreting structure, and the precise relation which they bear to the secreting cells. In his valuable paper published in the Philosophical Transactions for 1833, Mr. Kiernan describes and figures the anastomoses between branches of the hepatic ducts in the left triangular ligament of the human liver. He also refers to communications existing between the ducts in other situations, as in the membranous bridge stretching over the fissure of the umbilical vein, and upon the inferior surface of the diaphragm. In the same paper, this author gives a diagram of the manner in which he supposed the ducts to terminate in the lobules of the liver, and subjoins the following remarks:—"No such view of the ducts as that represented in this figure can be obtained in the liver. The interlobular ducts are in the figure seen anastomosing with each other. I have never seen these anastomoses, but I have seen the anastomoses of the ducts in the left lateral ligament, and, from the results of experiments related in this paper, I believe the interlobular ducts anastomose; I have never injected the lobular biliary plexus to the extent represented in this figure."

Since the appearance of this important communication, the subject has been much investigated both in this country and on the continent; but, as far as I can ascertain, no observer has yet succeeded in *demonstrating* the manner in which the ducts

commence, or has been able to show conclusively the precise relation which the hepatic cells bear to the biliary ducts. Various hypothetical views have been advanced.

Müller considered that the ducts terminated in blind extremities; E. H. Weber, in 1850, described ducts terminating in blind extremities upon the external surface of the cat's liver. Krukenberg, Schröder van der Kolk, Weber, Retzius, Theile, Backer, Leidy and others, have adopted the view that the hepatic cells lie within a basement membrane, and are of opinion that the cavity of the tubes in which the cells lie is continuous with that of the ducts. Lereboullet, in his memoir on the "Foie gras," published in 1853, advocates a similar view; but his representations are very diagrammatic, and for the most part taken from preparations examined by low powers. Almost all the drawings of authors, which represent the mode of origin of the ducts, are only offered as plans of the arrangement which they consider to exist, and are not pretended to be accurate copies of structure actually brought under observation.

Henle, Gerlach, and Natalis Guillot look upon the finest gall-ducts as communicating with spaces between the hepatic cells, into which the bile escapes, and from which it is received by the most minute ducts.

Handfield Jones and Kölliker describe the hepatic cells as forming a solid network composed of columns of cells, not bounded by any basement membrane, but lying in the meshes of the capillary network. The former excellent observer concludes that the ducts terminate by blind extremities, which lie amongst the cells at the peripheral parts of the lobule. The small cells lining these ducts are considered by Dr. Handfield Jones to be the chief agents concerned in the secretion of bile, and he looks upon the function of the hepatic cells as totally distinct from this. Professors Busk and Huxley, and Dr. Carpenter, appear to concur in this view, which places the liver in the same category as the supra-renal capsules, follicles of Peyer, spleen, &c. "In fact, startling as this view may at first appear, a very clear transition between the Peyerian follicles, &c., and the liver, is afforded by the tonsils; which, on the one hand, are identical with Peyer's follicles, in so far as they are solid vascular networks, whose

meshes are filled with a morphologically indifferent tissue, while, on the other hand, without differing from the liver in this respect, they resemble it in having these elements arranged around *diverticula* of the intestinal mucous membrane." "Finally, we suggest that the liver itself is but a huge tonsil—a vascular gland, with what might be termed a false duct."*

Kölliker offers the supposition, that the finest ducts impinge upon the columns of the network of hepatic cells, and makes the following remarks with reference to this point:—"Often as I have sought for a direct communication of the finest canals with the hepatic networks, I have not directly observed it; which is indeed by no means surprising, if we consider the softness of the parts with which we have to do; but unfortunately the result is a *hiatus* in the minute anatomy of the parts, which can hardly be made good by hypotheses. As such, however, I would offer the supposition, that the finest ducts impinge directly upon the columns of the network of hepatic cells, as the diagram shows, so that their cavity is terminated by hepatic cells."†

The conflicting opinions of observers appear to have been based upon inference and hypothesis rather than upon direct observation, and are embodied in diagrammatic figures. Some authors, agreeing in the main with Kiernan and the older observers, regard the liver as arranged upon the type of *true glands* with permanent ducts, while the latest authorities have endeavoured to establish the view, that this important organ is more nearly related to the *ductless glands*.‡

My own observations have been made upon the livers of several different animals, and I have tried very numerous methods of preparation, some with considerable success. The results of the examination of injected specimens precisely accord with the observations made many months before upon uninjected preparations.

The chief point which I hope to establish, with reference to the origin of the minute ducts, is the following:—

* Kölliker's Manual of Human Histology, translated and edited by G. Busk, F.R.S., and T. Huxley, F R.S., p. 126, note by the editors; 426 in the Appendix.

† Op. Cit. p. 118.

‡ An excellent abstract of the views upon the structure of the liver will be found in a paper by Professor Weber, "über den Bau der Leber," in the third part of the "Berichte der königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig," for the year 1849, and in Professor Kölliker's "Mikroskopiche Anatomie, 1852."

That the smallest biliary ducts are directly continuous with the tubular network of basement membrane in which the liver-cells lie; for, in favourable specimens, injection, forced in from the duct, will pass into every part of the tubular network, even quite to the centre of the lobule.* It is possible to inject the capillary network in the same preparation as that in which the ducts and cell-containing network are injected.

OF THE ULTIMATE RAMIFICATIONS OF THE DUCTS, AND OF THEIR CONNEXION WITH THE CELL-CONTAINING NETWORK.

Anastomoses of the Ducts.—The anastomoses of the large trunks, and of the branches given off by the larger interlobular ducts, are more numerous than, from the observations of anatomists, one would be led to suppose. These anastomoses, however, occur principally between the trunks, near their origin, as has been described; but, more rarely, different branches of the duct communicate with each other near the point where they join the cell-containing network. In most animals the latter communications are very scarce. In injecting one branch of the duct the injection will often pass out from another. Kiernan observed, that, if the left duct were injected with size or mercury, the injection returned by the right duct. This probably depends upon the intimate communications between these ducts in the transverse fissure of the liver, rather than upon the existence of anastomoses between the small branches near their points of distribution.

The anastomosis of small interlobular branches coming from opposite points, according to my observation, is very rare, as proved from the careful examination of well-injected specimens of the livers of different animals. Indeed, I have only been able to satisfy myself of its existence in one instance.

With regard to the communications of the larger trunks, and of the smaller branches, with the ducts from which they come off, it may be remarked, that not only do the right and left hepatic ducts anastomose, by the intervention of small, tortuous branches in the transverse fissure of the human liver, which form an intimate network, first described by Weber; but many of the branches which

* In the following pages the word "*duct*" is used to denote the tubes which carry off the secretion, in contradistinction to the secretory tubes, or "*cell-containing network*" in which the secretion is formed.

come off from the trunks are connected by smaller branches, which arise not far from the point at which they are given off, as represented in fig. 19. I have been able to prove, from very many injections, that these communications are very numerous indeed. Similar anastomoses occur to some extent in the case of branches of moderate size in the portal canals of the human liver; and in very good injections small branches coming off from a trunk at short intervals may be seen to communicate freely with the trunk itself, and with each other, by numerous intermediate branches, so that a network is formed at a short distance from the parent trunk (figs. 39 and 40 *c*). The meshes of this network are most variable in size and shape, and the tubes are more dilated in some places than in others (fig. 40a). Some of these branches are composed simply of basement membrane and epithelium, but the largest have a fibrous coat, though much thinner than that of the duct itself. Branches of the vein and artery, and of lymphatics (in the case of the larger portal canals), ramify among these ducts, and lie in the meshes of the network. In very good injections this network of branches of the duct is demonstrated in the adult, but in the fœtus the communications are to be shown with less difficulty, although the branches are not so tortuous and are less complex.

In the dog, and also in the calf, I have observed similar communications, but not so numerous as in the human subject.

The smallest branches of the duct may be readily followed, in tolerably good injections, to the surface of the line of hepatic cells, which bounds the portal canals, and not unfrequently they may be traced among these cells, in the human, and other livers. In the pig, the trunks may be seen gradually breaking up into their smaller branches, which are applied to the capsule of the lobule, and which appear to anastomose only very rarely, as above remarked. In the human liver an irregular network, in good injections, is to be demonstrated close to the larger branches of the ducts, and might be termed an *interlobular network;* but the arrangement is certainly not universal, nor does it seem to me to be sufficiently extensive to render it necessary to give it any special name: indeed, I have not been able to demonstrate it in the pig, seal, rabbit, horse, cat, or monkey. I am not prepared to affirm its absence in the above-

mentioned animals, but only remark that I have not been able to demonstrate it, and do not think that it exists.

It may be stated generally, that small branches of ducts carry off the secretion from that part of the lobule to which they are distributed. These small branches unite to form slightly larger ones, and these, again, to form others. *The smallest branches sometimes pour their contents at once into interlobular branches;—in other cases they are connected by a few transverse branches,—and sometimes, they form an irregular network before they are connected with the interlobular ducts.* This network, when present, is of a very different structure, and cannot be compared with that within the lobule described in Chapter IV. The *ductal* network exists in the most perfect form in the liver of the pig when this is not very fatty (fig. 51). When, on the other hand, the liver is fatty, this network is distended with ordinary hepatic cells containing much fat and free oil globules in considerable number.

Of the finest Branches of the Ducts, and of their junction with the tubes of the cell-containing network, in Mammalia.—It has been already stated that in injected preparations the smallest branches of the ducts can be traced up to the liver-cells. The walls of the small ducts are composed entirely of basement membrane, which is lined with epithelium, described in page 61. These ducts do not always lie in such close contact with the smallest branches of the vein, as is invariably the case with the larger trunks.

In many animals, particularly in the rabbit, and, to a less extent, in the human subject, and in some birds (turkey, fowl), the smallest branches of the duct are connected together so as to form a lax *network of ducts* which is continuous with the *lobular cell-containing network*, as represented in fig. 30. The branches are readily distinguished by their small diameter, and by the little granular cells of epithelium within them.

Some of the finest branches of the duct often appear to lie amongst the most superficial portion of the cell-containing network without being immediately connected with the tubes or cells in this part, but they may be followed for some distance, and may be seen to join a portion of the network which lies at a deeper part of the lobule;

the tubes at the superficial portion of the cell-containing network being continuous with small ducts which do not pass into the lobule. This point is well shown in fig. 33, taken from a drawing of the seal's liver, where two ducts in the upper part of the figure are seen to join the superficial part of the network, and another in the lower portion, is observed passing for a short distance amongst the tubes of the cell-containing network.

One of these penetrating branches has been figured by Gerlach, and, as he very justly observes, these branches are much narrower than the cells between which they lie, and hence concludes, very properly, that they cannot contain liver-cells. He supposes that they terminate by open mouths, into which the bile passes from narrow inter-spaces between the cells; but that this is not the case will presently be shown.

In the pig, numerous fine branches having reached the surface of the capsule, perforate it, and are immediately connected with a dense network, forming the most superficial portion of the cell-containing network, and consisting of very fine ducts, the tubes of which often contain small cells, granular matter, and perhaps oil globules, but usually no cells of the ordinary size are to be found within them; and, in consequence, the diameter of the tubes is much less than at a greater distance within the lobule (fig. 51). When the liver is very fatty, however, this part of the cell-containing network does contain cells filled with oil globules, as is shown in fig. 27, in which the *very narrow ductal portion of the tube is seen to dilate considerably at the point where it contains liver-cells.* The epithelial cells in the duct can often be traced quite up to the point which distinguishes the *efferent duct* from the *secreting portion* of the tube. This is well shown in fig. 27, which was taken with the camera from a preparation still in my possession; and which demonstrates these interesting points almost as clearly as when it was first mounted, upwards of two years since. The narrow ducts, and the wide secreting tubes, both contain a very little injection; and, in consequence of their accidental isolation from adjacent parts of the network, their continuity is seen distinctly. The delicacy and extreme narrowness of the ducts will readily explain the difficulty of demonstrating their continuity with the cell-containing network; for they almost invariably

break at the constricted portion, when an attempt is made to isolate them; and, unless this isolation can be effected, it would be impossible to prove that such an arrangement really exists. In this preparation, by an unusually lucky accident, the cell-containing network has broken, instead of the narrow portion of the duct, which is protected, as it were, by lying upon the walls of a small artery. The further continuity of the network is shown by dotted lines. I have seen the same point in several specimens, but never in one which shows a greater number of minute ducts, and their points of connexion with the tubular network in which the secreting cells lie, with greater distinctness. These narrow ducts are only 1-3000th of an inch in diameter; while the expanded portion, in which the liver-cells lie, and with which they are immediately continuous, is upwards of 1-1000th of an inch in width.

The connexion between the finest ducts and the cell-containing network, from an injected specimen of the human liver, is represented in fig. 46; the hepatic cells have been much altered in preparing the specimen from which the drawing was copied.

In fig. 42 is shown a similar arrangement in a portion of human liver, which had been treated with soda, and kept for some time in strong syrup. Here the epithelium of the ducts is well shown, but the specimen has been flattened somewhat by the pressure of the thin glass. Fig. 41 is a representation of another section of the same liver, which has not been subjected to pressure, in which the *narrow ductal part* of the tube contrasts remarkably with the *wide secreting portion* which is continuous with it. In the human fœtus, the connexion between the duct and cell-containing network is shown in fig. 39, at *a*, and in fig. 40 it is represented in the liver of the calf. In the seal, the hepatic cells are small, and injection readily passes into the tubes which contain them. The small ducts are comparatively few in number, but their course in this animal is very easily traced, and they can be well seen through the thin wall of a small portal vein which has been injected with clear size. In fig. 28, at *c*, this point is well shown upon the surface of a branch of the portal vein, and in fig. 33 the connexion between the ducts, and the cell-containing network in the liver of the same animal is represented.

Fig. 30 is a copy of a drawing of a thin section of rabbit's

liver, taken from a thin and emaciated animal, in which the cells were much smaller than natural, and the diameter of the tubes much less than in a healthy state. In many situations the tubes contained only granular matter, and no cells could be distinguished. Narrow granular lines communicating at intervals with each other, were seen separated by wide clear spaces (capillaries). The injection ran very readily, and in some places distended these tubes to the extent shown in fig. 32, and thus the clear capillary space was obliterated. In this specimen the very fine ducts were injected to a greater extent than can usually be effected; but even here I am persuaded that the injection has not entered into many of them. I believe it to be nearly impossible to inject all or even the greater number of the minute ducts; for by the pressure which those filled with injection must necessarily exert upon the adjacent ones, the latter become completely occluded, and no injection whatever can enter. Their extreme tenuity, and the number which lie in close apposition, preclude the possibility of demonstrating them in the uninjected state, except in a few rare instances by a peculiar method of preparation.

Birds.—In the turkey, and also in the fowl, I have been able to trace the continuity of the ducts and cell-containing network in injected specimens. The abundance of epithelium in the ducts forms a great obstacle to perfect injection, and the excessive delicacy of the capillaries prevents the injection of much water without rupture. From this cause I failed in many attempts to obtain demonstrative preparations of the arrangement in the bird's liver.

In the chick of the 15th day, and also in that of the 21st day, the continuity was clearly made out in some preparations which had been previously hardened in alcohol and soda.

Reptiles.—In the newt I have traced the course of the ducts in an uninjected specimen, and have succeeded in making a good injection of the ducts of the adder, in which animal the continuity of the very narrow ducts, with the wide tubes containing the liver-cells, could be clearly traced.

Fishes.—In the investigation of the anatomy of the ducts in the class of fishes, the greatest difficulties presented themselves, and very numerous were the failures which I met with in trying to inject them. The difficulty arose partly from the delicate

nature of the vessels, which very frequently were torn in injecting them with water, and partly from the soft, pulpy, and exceedingly fatty condition of most of the livers of this class of animals.

In the flounder the connexion is shown in fig. 66, *b c* and *e*. The secreting tubes represented are much smaller than is usual in this class, depending principally upon exosmose of their fluid contents, owing to which the tube shrinks, and its outline is clearly distinguished. I have succeeded in injecting the ducts of the sturgeon and frog-fish, and the connexion between the very narrow ducts and the cell network is represented in fig. 64, *a c*, and in fig. 65, *g h k*.

Even in the fatty liver of the cod I once traced the continuity of the narrow ducts, with the very wide tubular network distended with cells containing oil and free oil globules.

In injecting the livers of fish, the injection must be diluted with weak spirit, or it does not penetrate to the smallest branches. The colouring matter which is employed is the same as in other cases. Often the particles of the injection accumulate in some of the finer ducts, forming what appears to be rounded and slightly dilated extremities; for the further continuity of the tube cannot be detected. Indeed, so perfect is the resemblance, that it is only by carefully examining many different specimens that one becomes convinced of its fallacy.

In all four classes of vertebrate animals, the arrangement of the ducts, and the relation which they bear to the secreting cells, is very similar. I have seen both in injected, and also in uninjected specimens, the communications between the finest ducts and the cell-containing network. Of the nature of this continuity there can, I think, be no doubt. I can conceive no other explanation of the facts I have observed, or of the appearances presented by my preparations. The observations upon uninjected specimens, shown in figs. 41, 42, and 43, were made early in 1854, many months before I had succeeded in injecting the ducts. The arrangement of the most minute ducts varies somewhat in different animals, as has been described. In some they form a network of very narrow tubes, continuous with those in which the liver-cells are contained; in others, these communications are exces-

sively few in number; while in some, I do not think they exist at all. But I would not express myself positively upon this point, for I feel persuaded that in the most perfect injection which I have yet made, the minute ducts have not all been injected. According to the observations just described the cells of the liver correspond in all essential characters to the secreting cells of other glandular organs. They lie within a cavity of basement membrane, which is here arranged so as to form a network, the tubes of which are directly continuous at various points with very narrow efferent ducts. Now, this narrowing of the duct before it becomes connected with the *secreting* portion of the organ, is seen in other glands. In the kidney, the total diameter of the *straight and ductal portion* of the renal tube is considerably less than that of the *convoluted* and *glandular part*, although the central cavity is wider, which allows of a very rapid removal of the secreted products formed in the convoluted portion of the tube. The cavity of the very narrow ducts of the liver, although so small, would doubtless admit the passage of a larger quantity of fluid, within a certain time, than the variable and irregular interstices existing between the cells and the basement membrane in the secreting portions of the network. A somewhat similar arrangement occurs in many other glands. In the liver, where the secretion is highly elaborated, and slowly removed from the secreting structure in a concentrated form, we should naturally expect to find the contrast between these two different portions of the gland even more remarkable than in the examples referred to. This is really the case.

Epithelium of the Smaller Ducts.—The larger ducts, as is well known, have a thick lining of columnar epithelium; but the cells become shorter towards the smaller channels. In the smallest tubes, the cells of epithelium are somewhat flattened, and are of a circular or oval form, which latter, in many instances, is due to the ducts being much stretched in preparing the specimen. These minute cells have a pale granular appearance, and it is not often that a nucleus can be distinctly seen within them. The epithelium of the ducts is not dissolved by caustic soda so readily as the liver-cells; indeed, the former cells are scarcely altered by weak solutions, while the latter are rendered very soft and trans-

parent (page 40). The quantity of this epithelium in the smaller ducts varies very much; sometimes it completely lines the tube; in some instances it is so abundant as apparently to leave no distinct cavity in the duct (a condition I have met with in the rabbit, turkey, and fowl); while it is not uncommon to find some of the finest ducts, containing only a very few cells, scattered at irregular intervals over the basement membrane, of which the walls of the small ducts are entirely composed. In a perfectly normal condition, when the minute ducts are undisturbed by manipulation, and are examined in a proper medium, they are generally seen to be lined by epithelium; but, from the extreme minuteness of these ducts, and the tenuity of their walls, and not less from the very delicate nature of the epithelium itself, there is no wonder that we should fail in making out distinctly their epithelium in every instance in which we search for it.

It is not easy to lay down with precision the exact point at which the change in the character of the epithelium of the ducts occurs; but it appears to me that the alteration is a gradual one, and that the cells become shorter and shorter as the diameter of the ducts diminishes. In ducts of the 1-600th of an inch, and in smaller ones, the epithelium presents the characters above described.

It will be found that this ductal epithelium does not pass by insensible gradations into the secreting epithelium, or hepatic cells, but ceases abruptly at the point where the narrow duct becomes continuous with the wide secreting cell-containing network. Nowhere, that I know of, can be seen, in so small a space, a more striking contrast between secreting epithelium, and that which lines an efferent canal. The large characteristic cell of *glandular epithelium* ceases at the point where the small cell of *protective* or *ductal epithelium* commences.

The arrangement here referred to, is very similar to that which is met with in the gastric gland. It is only in the lower part (stomach tube) that the cells of spheroidal epithelium,—which alone there is every reason to believe take part in the secretion of the gastric juice,—are found. The upper portion or duct (stomach cell) is lined with columnar or subcolumnar epithelium.* In these glands the secreting cells are not arranged with any order or

* Todd and Bowman's Physiology.

regularity round the basement membrane of the tube, as is the case in the kidney; but appear, in the ordinary state of the parts, almost to fill its cavity, so that the secretion, having escaped from the cells, must pass off by the slight interstices which exist between them and the membranous wall of the tube. As I have before observed, the same irregularity occurs in the arrangement of the secreting cells in the tubes of the liver, and also, but in a less remarkable degree, in the secreting portion of many other glands, as the pancreas, the lacteal glands, and sweat glands.

In a few instances I have seen tubes containing liver-cells apparently lined with the delicate epithelium of the ducts, an observation which would tend to confirm those of Mr. Wharton Jones, who has seen liver-cells in the smaller ducts. It is probable that in these cases the cells have entered the *ductal* portion of the tube accidentally. The tubes in the cases referred to, however, were uninjected, and therefore I am not disposed to lay much stress upon the observation.

The epithelium of the small ducts presents much the same character in all the animals which I have examined. In figs. 42 and 43, *g*, the characters of the epithelium in the more minute ducts of the human subject are represented. In the cat it is shown in fig. 35; and in fig. 34, in the lamb. In the latter figure an opportunity is afforded for contrasting the characters and size of these small granular cells with the large hepatic cells.

Dr. Handfield Jones' Observations.—My friend, Dr. Handfield Jones, has arrived at a totally different conclusion with reference to the nature of the smallest ducts, and the epithelium which is contained within them. The latter he regards rather in the light of nuclei, "which are set close together in a subgranular or homogeneous basic substance;" and to these nuclei he assigns the important office of absorbing the material which is secreted by the liver-cells, and which he considers bathes the terminal extremities of the ducts in which this epithelium is contained, or with which it is in direct continuity. Dr. Handfield Jones also observes, that there is seldom any trace of basement membrane to be found in ducts having epithelium of this character, and, he considers that, the basement membrane imperceptibly ceasing, the ducts terminate in this epithelium. Upon such a view, however, I should be

quite unable to explain a number of appearances which I have often seen; and I have been led to a totally different conclusion upon this point, as has been fully discussed. That view seems to me to be the only one, with reference to the termination of the ducts, compatible with the facts which have been observed. When the ducts are injected, according to the method described in Chap. I., the epithelium and the injection may be seen very distinctly with a quarter of an inch object-glass, in narrow tubes, often not more than the 1-3000th or 1-2000th of an inch in diameter, and I have never been able to satisfy myself of the existence of blind extremities. The investigation, however, must be admitted to be a most difficult one, and the question at issue of such a delicate nature, that I am very unwilling to convey an impression of speaking too confidently in favour of the results of my own work, or in the least degree to appear to disparage the conclusions which other observers have arrived at,—no matter how essentially these conclusions may be at variance with my own, or how strongly I may feel convinced in my own mind of the truth of my deductions, and of the correctness of the data upon which they have been founded.

Diameter of the finest Ducts.—The diameter of the finest ducts can only be obtained approximatively; for when not injected, they can only be demonstrated distinctly in fortunate specimens, and are probably somewhat narrower than during life. When injected, on the other hand, they are usually distended, and somtimes to a very considerable extent. In the pig, the smallest branches containing a little injection are not more than the 1-3000th of an inch in diameter; in the human subject, about 1-2500th; in the seal, 1-3000th; in some fishes, not more than 1-5000th.

The diameter of the cavity of the tube and the total diameter of ducts of different sizes are shown in the following Table:—

	External Diameter.	Internal Diameter.
Pig	·008	·004
	·006	·003
	·001	·001
Human Subject	·01	·0045
	·002	·002
Human fœtus	·01	·0045
Cat	·015	·0075
Monkey	·02	·01
Seal	·001	·001
	·0003	·0003

CHAPTER VI.

SOME GENERAL OBSERVATIONS UPON THE ANATOMY AND PHYSIOLOGY OF THE LIVER:—THE VERTEBRATE LIVER.—THE VERTEBRATE AND INVERTEBRATE LIVER COMPARED.—THE LIVER AND KIDNEY COMPARED.—POSITION OF THE LIVER AS A SECRETING ORGAN.—SUMMARY.

The Vertebrate Liver.—The vertebrate liver may be looked upon as consisting essentially of two distinct systems of channels arranged so as to form *solid** networks which mutually interlace with each other. In one of these networks lie the secreting cells, often arranged so as to form only a single row, which is, therefore, surrounded on all sides by the blood containing the elements from which the bile is formed. The fluid bile escaping from the cells into the network of tubes, flows towards the surface of the lobule where the ducts lie. In the other network flows the blood, but in a precisely opposite direction to that which the bile takes.

The *portal blood* reaches the capillaries of the lobule at many different points upon its surface, and all the blood from these numerous sources at the circumference, must pass through capillary vessels which converge towards the single radicle of the hepatic vein in the centre; and hence it follows that the circulation of this blood must be much more rapid in the central part of the lobule than near the portal surface. This perfectly harmonizes with many anatomical facts which I have before alluded to. The blood which has just arrived from the intestines, loaded with recently absorbed constituents, flows very slowly, in order to give time for the action of the liver cells upon it, and for the removal of some of these substances from it. When these have been separated, its slow course is no longer necessary, and as it becomes purer it flows with increasing velocity, until it is at last poured into the large inferior cava.

By the very simple and beautiful combination of the elementary

* This term was first employed by Mr. Bowman, *vide* article, "Mucous Membrane," Todd's Cyclopœdia of Anatomy and Physiology.

tissues of the liver, so as to form minute portions resembling each other, or *lobules*, the most complete changes in the circulating blood are ensured, while the circulation is retarded in the least possible degree compatible with the alteration to be produced; and at the same time the anatomical elements, through the intervention of which these changes are effected, are combined in such a manner as to occupy the smallest possible amount of space.

The cells in all parts of the network have, no doubt, the power of forming bile, but in different degrees; those quite close to the centre of the lobule, have often been observed to be filled with yellow granules. There is no reason for supposing that the secretion is passed from cell to cell, and at last into the duct; for if this were the case, we should at least expect to find greater difference in the cells near the ducts than really exists; and it must be remembered that in many animals in a state of perfect health, no difference whatever is to be demonstrated. The cells at the circumference of the lobules of the human liver usually contain a much larger quantity of oil than those nearer the centre, which is just what we should anticipate when we consider that the portal blood, rich with the freshly absorbed constituents of the food, first reaches these marginal cells. The direction of the circulation is the reverse of that which we should expect to find if the secretion were transmitted from cell to cell, as most authorities in the present day insist upon. For if this were really the case, it seems to me that we should be forced to admit that the blood flowed through the superficial part of the capillary network to no purpose. On the other hand, the anatomy of the organ almost forces upon us the conclusion, that the cells nearest to the duct take the most active part in the secretion, and that the blood gets gradually rendered more free of substances from which the bile is formed, as it travels along the capillary tubes from circumference to centre, with a gradually increasing rapidity of movement. Lastly, the assumed absence of any channel in which bile could flow, ceases to be a tenable objection, since it has been shown to be comparatively easy, provided that certain precautions be observed in conducting the operation, to force injection into a channel which does exist. For if, by artificial means, fluid can be made to pass in an opposite direction, within the tubes of this

cell-containing network, up to the hepatic vein, how very sure may we feel of the existence of such a channel along which the bile flows during the life of the organ.

This large and important organ presents us with an example of gland structure in which the different tissues of which it is composed are arranged in the most advantageous manner it is possible to conceive. The secerning cells and the blood are brought into the closest proximity possible. The blood containing the crude elements is separated from the cells whose office it is to elaborate these constituents, only by the intervention of the thin capillary walls and a membranous partition, under ordinary circumstances not visible, and so delicate that its existence is disputed by many great authorities. The areolar tissue, which serves to support the capillaries of most glands, is here absent, and the wall of the capillary comes into close contact, and in many instances is incorporated with the thin transparent membranous tube in which the liver cells lie.

The alteration in volume which the cells may be made to undergo by artificial means, indicates how very simply a channel may be produced when the organ is in its natural condition. The two sets of tubes mutually adapt themselves to each other; and if the secreting tubes be unusually empty, the vascular tubes admit more blood. It has been already pointed out what a very large proportion of fluid the capillary vessels of the liver are capable of containing over and above what may be assumed to be their normal quantity, and also how the distension of the vessels, by forcing in fluid in one direction, promotes the passage of liquid through the cell-containing network in the opposite direction. Careful reflection upon some of these circumstances assists much in the comprehension of many of the morbid changes which take place in the liver.

The bile having arrived at the smallest ducts, without doubt undergoes further changes. It is not improbable that the oxygen brought by the arterial blood which flows in the vascular network, through the meshes of which the ducts pass, exerts some influence upon it. This, however, has not been proved. The most important alteration which the bile now undergoes, is concentration. Water is removed, and the proportion of solid constituents gra-

dually increases as the bile passes slowly along the thin-walled, tortuous ducts. It is this change which serves to explain the comparatively slight increase of diameter of the ducts, in proportion to the great number of branches which they receive. Thus the apparent disproportion between the vast amount of secreting structure and the small efferent ducts, vanishes, when we consider how highly concentrated the bile becomes before it reaches the large duct. Bile contains a larger proportion of soluble constituents than any other liquid secretion.

The manner in which this concentration is effected has been alluded to. In those animals provided with a gall-bladder, it has been shown experimentally by Bidder and Schmidt that much fluid is absorbed while the bile remains within this viscus. It is interesting to observe, that the arrangement of vessels and lymphatics in the portal canals and transverse fissure of the liver, is similar to that which is met with in the gall-bladder. The bile is brought into very close relation with the vessels, by entering the little cavities, *parietal sacculi,* in the coats of the ducts, and in the vasa aberrantia, which are always surrounded by numerous branches of the vein and artery, and by lymphatic vessels.

In some instances the inspissation of the bile is carried to an abnormal extent, and small, tolerably hard granules of biliary matter are eventually produced. These often form the nuclei of gall-stones, and sometimes accumulate in great numbers in a branch of the duct. Although a calculus might become impacted in a duct, the free transmission of the bile is fully provided for by the numerous anastomosing branches, just external to the duct itself, which have been described in Chapter III.

The Vertebrate and Invertebrate Liver compared.—It has been remarked by many writers, that there is a great difference of structure between the livers of the vertebrata and the invertebrata; but the more carefully the vertebrate liver is examined in its minute details, the stronger becomes the evidence that both resemble each other in many essential particulars. Nay, in some of the lowest of the invertebrata, the general minute anatomy of the liver closely accords with that of the organ in the highest animals. In the large intestine of the common frog, a small entozoon of the Trematode order is very often met with. In some of these, which

were taken from the body of a starved frog, the biliary follicles and their ducts were very distinct. The cells in their interior contained colouring matter, and but very little oil, consequently the follicles were somewhat shrunken, and could be examined very satisfactorily. The follicle terminates in a cœcal extremity, but is prolonged at the opposite end into a very narrow duct, which is soon joined by the ducts from other follicles. Suppose the cœcal extremities extended, and communicating with each other, so as to form a network, and an appearance closely resembling the drawing of the connexion between the ducts and cell-containing network in fig. 27 would result. The cells appear to contain colouring matter and oil, either in a granular state or in the form of distinct globules, in all classes of animals; their general character is very similar, and they lie in the tube or follicle which contains them without order or regularity, their form being influenced to a considerable extent by mutual pressure. It is impossible to help seeing a similarity in the arrangement of the cœcal follicles, with their narrow necks, around some of the ducts in the higher animals, and comparing this with the follicular condition of the entire organ in many of the mollusca and crustacea.

In the different members of the animal creation, the liver-cell preserves certain constant peculiarities; and in the development of the young animal, this cell soon attains the characters which it bears throughout life, except that it contains a greater number of nuclei at this early period. The comparison is exceedingly interesting, as shewing the great similarity in the essential arrangement of the liver in animals occupying such opposite positions in the animal scale.

The Liver and Kidney compared.—The bile and the urine, the two most important secretions in the body, have often been contrasted, and their opposite or complementary nature has been pointed out. It is interesting to compare the anatomy of the glands which secrete these dissimilar fluids.

The *kidney* is an organ destined for the rapid removal of substances, the most important of which, at least, exist pre-formed in the blood, largely diluted with water. A tortuous tube of basement membrane, closed at one end, lined in its interior with cells, but having a free central cavity, is the essential apparatus by

which this is effected. At the closed extremity of the tube is a special provision for the separation of water, which, as it passes down the central cavity, readily dissolves away the soluble matters which the cells have separated from the blood. The solution passes down the tube, and without undergoing any further change, is very soon removed altogether. So very important is the rapid removal of the urinary constituents from the organism, that in those animals in which a sufficient quantity of water for their complete solution cannot be afforded, there exists a most perfect and beautiful arrangement by which this object is attained, but in a totally different manner. Not only is there a cavity throughout the entire length of the tube, but the cells around it are furnished with vibratile cilia, by the action of which even solid particles are whirled down the tube with a velocity greater than that of the circulation of the blood in the capillaries.

In the *liver*, on the other hand, we have an organ not only for the separation of substances very recently introduced into the organism from the portal blood, but for the slow elaboration and conversion of these into very different products which serve important ulterior purposes in the economy, and which are principally re-absorbed into the blood, while at the same time, it is probable that a change occurs in other constituents of the blood in its passage through the liver. A network of delicate tubes containing large secreting cells in their interior, arranged irregularly and nearly filling the cavity, without leaving any well-defined channel for the passage of the secretion, is the essential apparatus for the formation of the proper secretion of the liver. The secretion, when formed, may remain for some time in the tubes, but slowly makes its way in an opposite direction to that in which the blood flows, through very narrow channels, either between the cells themselves, or between these and the walls of the tube, until it arrives at the narrow tubular duct. Still passing slowly along these delicate tubes, it becomes exposed to the influence of arterial blood, while much of its water, probably holding in solution substances capable of permeating the basement membrane in this direction, is re-absorbed by the veins and lymphatics, which form an intimate plexus round the ducts. It has been shown how effectual is the provision for the concentration of the bile throughout every part

of the ducts from their commencement to their termination. Unlike the urine, the bile undergoes important alterations after it has been set free by the cells in its course along the ducts, and it is probable that but a small proportion of the total quantity formed in the liver is entirely removed from the organism without undergoing many other changes previously.

Position of the Liver as a secreting organ.—The liver, then, is to be classed with the true glands. In all classes of animals it consists of a *formative portion* and of an *efferent duct,* the epithelium in these two situations presenting wide and characteristic differences. It contains both absolutely and relatively a greater proportion of true secreting structure than any other organ. Its secretion is of the most complex chemical composition, and differs more widely from any known constituents of the blood than any other secreted product; so also it seems to serve a greater number of important purposes in the economy, while from the most recent experiments it appears that the amount of bile separated by the liver in twenty-four hours is larger than that of any other liquid secretion, and at the same time it contains a higher per-centage of solid matter.

The early appearance of the liver,—its large size both in the embryo and in the adult, its almost universal presence and general similarity of structure in all classes of animals, the complex and highly concentrated nature of its secretion and its large quantity, justify us in regarding the liver as the most important glandular organ in the body. The large size and vast number of its cells, their close proximity to the blood, and the beautiful arrangement of the other anatomical elements of which it is composed, render it, I think, the most perfect example of gland structure with which we are acquainted.

SUMMARY.

The livers of all vertebrate animals are penetrated in every part by two sets of channels, which alternate with each other. One series, *portal canals,* contains a branch of the portal vein, hepatic artery, and hepatic duct, *interlobular;* and the other series, *hepatic venous canals,* is occupied by a single branch of the hepatic vein, *intralobular.*

Division of the organ into Lobules.

The vessels and ducts ramifying in the portal canals are ultimately distributed in such a manner that they serve to divide the organ into little masses, and thus map out spaces, or *lobules,* each of which contains all the structural elements of the organ, and may be regarded as an *elementary liver.*

In the intervals between the fissures by which the portal vein, artery, and duct are conducted to the lobule, its capillary vessels and its secreting structure are continuous with those of adjacent lobules.

The size and form of the lobules differ much in different animals; but their essential structure is the same in all, except in the pig, in the Polar bear, according to Müller, and in the Octodon Cummingii (one of the rodents), according to Hyrtl.

In these exceptional cases the liver is divided into a number of distinct and separate lobules, each provided with a capsule of its own, just as the kidney of the porpoise and of the seal is divided into a number of separate renules.

In the *pig* each lobule is provided with a separate fibrous capsule of its own, and is, therefore, completely isolated from its neighbours. Branches of the portal vein, artery, and duct run between them, and give off branches to contiguous lobules. In the intervals between the fibrous capsules areolar tissue can frequently be demonstrated.

In all cases, upon a section, the lobule is seen to be bounded externally by branches of the vein, artery, and duct, and in the centre is situated a small branch of the hepatic vein.

Areolar Tissue in Portal Canals.

In the liver of the human subject, and in that of vertebrate animals generally, with the exceptions above mentioned, the lobules are not separated from each other by any fibrous partition, and there is no areolar or fibrous tissue, or prolongation of Glisson's capsule between them, or in their interior.

The vessels at their entrance into the liver, and as they run for some distance in the larger portal canals, are surrounded with much areolar tissue; but the disposition of this texture about the vessels of the liver is very similar to its arrangement about the larger vessels distributed to other organs.

Intimate Structure of the Lobule.

The *lobule* itself is composed of a solid capillary network, and of another network composed of a very delicate tubular membrane, in which the liver cells are contained.

These networks mutually intertwine with each other.

The capillary network is directly continuous with the smallest *interlobular* branches of the portal vein, distributed upon the circumference of the lobule on the one hand, and with the small *intralobular* branch of the hepatic vein arising in its centre upon the other. The vessels of the network converge toward the centre of the lobule.

Small branches of the *artery* open into the venous capillaries of the lobule, near its circumference, and the diameter of these small branches is considerably less than that of the venous capillaries into which they open; the former not more than the 1-4000th of an inch in diameter, the latter about the 1-1600th.

In all cases, the blood, enriched with constituents recently absorbed from the intestine, flows with a gradually increasing rapidity from the circumference of the lobule towards its centre, while the bile flows in a precisely opposite direction.

Of the Liver Cells and of the Tubular Network in which they lie.

The liver-cells lie within a tubular network of basement membrane, which separates them from the walls of the capillaries. In many cases, however, these thin membranous tubes cannot be separated, and are, no doubt, incorporated with each other.

The cells are not attached to the basement membrane of the tube, but lie in its cavity. Among them free oil globules and

granular matter are often found. Usually, there is only room for one row of cells, but sometimes two or more lie across the tube. In the embryos of mammalia, in young animals generally, and in fishes, there is room for several rows to lie transversely across the tubes of the cell-containing network.

The cells near the margin of the lobule take the most active part in the formation of bile. The secretion passes along the tubes in the slight interstices between the cells and the basement membrane, and coloured fluid can be forced along these same interstices in a direction the opposite to that in which the bile flows during life, and, therefore, at a great disadvantage. The amount of space is in great measure determined by the quantity of blood in the vessels, and it is liable to great alteration.

The cell-containing network is directly continuous with the most minute ducts, which ramify at the circumference of the lobule, and it terminates in the centre by loops, which lie close to the intralobular vein.

Of the Finest Ducts.

The tubes of the cell-containing network are many times wider than the narrow thin-walled ducts with which they are directly continuous.

The smallest *ducts* are lined with a very delicate layer of epithelium, composed of *flattened cells* of a circular form, contrasting remarkably with the large *secreting cells,* which are not arranged in any definite manner within the tubes of the network.

The tubes of the cell-containing network are about 1-1000th of an inch in diameter, or more, but the finest ducts are commonly not more than 1-3000th, and they are often seen even less.

The smallest ducts in some animals branch very freely, and the branches communicate with each other at intervals. In others they pursue a long course without branching, and in the pig they form an intimate network upon the surface of the lobule. In fatty livers of the pig, however, this ductal network often contains liver-cells loaded with oil globules.

As the ducts increase in size they are provided with a fibrous coat, and the epithelium in their interior becomes columnar.

The *interlobular ducts* do not anastomose.

Sacculi in the Coats of the Ducts.

When the fibrous coat reaches a certain degree of thickness it contains numerous little cavities, or *sacculi,* arranged entirely round the tube in the pig and in most animals, but forming two parallel rows, one on either side of the duct, in the human subject.

These little sacculi often communicate with each other in the coats of the duct. The smaller branches of the duct also anastomose frequently, either in the coats of the duct or just external to them.

The sacculi appear to serve the purpose of bringing the bile in the thick walled ducts into closer relation with the vessels which surround them, and especially with the branches of the artery which are distributed to their coats.

Of the Vasa Aberrantia and of the arrangement of the Vessels around them.

In the transverse fissure of the human liver and some others, and in the large portal canals, are found some peculiar branches of the duct, *vasa aberrantia,* with numerous sacculi on their walls, which anastomose with each other and form a network.

In the same localities in the human subject, and in the gall-bladder, a very peculiar arrangement of the vessels occurs. Both arteries and veins form a network, and each branch of the artery is accompanied with two branches of the vein, one on either side of it.

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